EFFECTS OF INTER-ROW SPACING AND PLANT DENSITY ON PERFORMANCE OF SESAME (*SESAMUM INDICUM* L.) IN A NIGERIAN SUDAN SAVANNA

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ABSTRACT: *Field trials were conducted during 2006 and 2007 rainy seasons at the University of Maiduguri Teaching and Research Farm, Maiduguri, Nigeria, to determine the influence of inter-row spacing and plant density on growth, development and yield of sesame. The treatments comprised three inter-row spacing (25, 50 and 75 cm) and four plant densities (2, 4, 6 and 8 plants/stand). A split plot design was used where inter-row spacing was assigned to the main plot and plant density was assigned to the sub plot and replicated three times. Results showed that plant height significantly decreased with increase in inter-row spacing. The tallest plants were recorded for 25 cm at 3 and 6 WAS, but values declined significantly at closer inter rows as the growth period progressed. Dry stalk weight increased significantly with increase in spacing and plant density. Seed yield was significantly higher at 50 cm than 25 cm or 75 cm spacing in 2006 and slightly higher in 2007. The 75 cm spacing recorded significantly higher seed yield than 25 cm or 50 cm spacing for the combined mean. Seed yield was also significantly higher for 6 plants / stand than the other plant densities in 2006. In 2007, 4 plants / stand significantly realized higher seed yield than the other treatments. There were significant interactions on plant height, number of days to 50% flowering, seed yield and seed weight. The interactions showed that seed yield was significantly higher at 25 cm with 6 plants per stand in 2006 and at 25 cm with 4 plants per stand in 2007. The linear relationships showed that seed yield was negatively correlated with plant height at 3 WAS (r = - 0.87***), days to 50% flowering (r = - 0.67***), dry stalk weight (r = - 0.40***) and seed weight (r = - 0.71***). Seed weight was positively correlated with days to 50% flowering and dry stalk weight (r = 0.40*** to 0.68***). Grain yield of sesame could therefore be enhanced by sowing at 50 cm x 25 cm spacing with 4-6 plants per stand (320,000 – 480,000 plants/ha) to reduce plant competition in Nigeria's Sudan savanna.*

Key Words: *Sesame; inter-row spacing; plant density; seed yield; plant competition; Sudan savanna*

INTRODUCTION

Sesame (*Sesamum indicum* L.) otherwise known as beniseed in Nigeria belongs to the division Spermatophyte and family Pedaliacea is believed to have originated from tropical Africa [1]. It is one of the oldest cultivated crops and perhaps the most important oil seed in the world [2]. About 50-60% oil is obtained from the seeds and it is of excellent quality due to the presence of natural antioxidants such as sesamol and sesaminol [3]. The oil is used in making salad, or cooking oil, as margarine and soap. It is also used in paints, cosmetics, perfumes and insecticides [4,5]. The demand for this important commodity is on the increase in the world market. Anon[6] reported that Chinese Agro product companies demanded for over 15,000 metric tonnes valued at $12 million or ₦1.86 billion, in which Nigeria was expected to generate about $150 million equivalent to ₦19.8 billion in 2004 cropping season.

The average grain yield per hectare has been reported to be relatively low in most producing countries; between 300-350 kg/ha [7,8,9]. This low productivity has discouraged growers thereby reducing the total area under sesame cultivation. Among the factors responsible for the low yield in Nigeria are poor agronomic practices by Nigerian farmers [10], his coupled with the low fertility status of soils and perhaps other factors. Sesame production in Nigeria is seriously affected by low plant population and wider inter-row spacing. Katung [11] reported that yield increase occurred with an increase in plant density up to an optimum of 400,000 plants/ha beyond which no further increase was observed. Inter-row spacing has also been reported to influence seed yield and other agronomic parameters of sesame. Olowe and Busari [12] reported that total dry matter increased as the inter-row spacing increased from 30 cm to 90 cm. Yield increase was also observed by increasing inter-row spacing up to 60 cm. Plant spacing and plant density trials conducted at Mokwa by Institute of Agricultural Research (IAR) indicated that yield increased with increase in inter-row spacing up to 47 cm [14] reported plant densities of 333,000 to 400,000 plants/ha as optimal. However, Adeyomo *et al*. [15] reported the optimal population of sesame to be between 133,333 and 266,667 plants/ha and is achieved with a spacing of 50 cm x 15 cm. Similarly, Olowe and Busari [12] recommended a spacing of 60 cm x 10 cm or 60 cm x 5 cm, which resulted in a population of 166,667 and 333,333 plants/ha, respectively.

The yield of any crop is a very complex quantitative character resulting from different factors, the more important of them being the yield per plant and number of plants per unit area [16]. Although some study have been done on sesame inter-row spacing and plant population density in northern Guinea savanna agro ecology of Nigeria, there is paucity of research work on these very important management practices in the Sudan savanna agro ecology. This study was therefore conducted to determine optimum inter-row spacing and plant density for sesame production in the study area.

MATERIALS AND METHODS

Experimental site and weather situation

Field experiments were conducted during the 2006 and 2007 rainy seasons (July-October) at the University of Maiduguri Teaching and Research Farm (15° 50'N; 13° 05'E) in Sudan savanna ecological zone to determine the effects of inter-row spacing and plant density on sesame performance. The physico-chemical analysis of the soil of the experimental site showed that the texture was sandy loam with 63% sand, 19.1% silt and 17.9% clay. Total N (1.3g/kg) and available P (70 mg/kg) were moderate, available Ca (17.2 Cmol/kg) and Mg (3.60 Cmol/kg) were high, and K (0.24 Cmol/kg) was low, while organic carbon (2.2g/kg) and organic matter (3.7g/kg) were very low. Thus, the nutrient content of the soil was low according to the FAO rating [17].The total amount of rainfall received for 2006 and 2007 were 481.0 mm and 572.0 mm, respectively.

Experimental design and treatments

The experiment consisted of 12 treatment combinations of three inter-rows spacing (25 cm x 25 cm, 50 cm x 25 cm and 75 cm x 25 cm) and four plant densities (2, 4, 6 and 8 plants/stand) laid out in a split plot design and replicated three times. Inter-row spacing was assigned to the main plots while plant density was assigned to the sub plots. The gross plot size was 4 x 3 m (12 m^2) and a net plot size of 3.5 m x 2.5 m (8.75 m^2). The land was harrowed with a tractor-driven disc and plots manually prepared. A blanket application of 30 kg P/ha using single super phosphate (18% P_2O_5) fertilizer was done during land preparation. Seeds were sown at the specified spacing and later thinned to the desired density per each plot at two weeks after sowing (WAS). Two manual hoe weeding were carried out at 4 and 9 WAS.

Data collection and statistical analysis

Four plants were randomly selected from each plot and tagged for the purpose of recording data on plant height at 3, 6 and 9 WAS; and dry stalk weight. Days to 50% flowering, seed yield per hectare and seed weight (standard matchbox full) were also recorded. The mature plants were harvested when the colour of the leaves changed from green to yellow; stacked in an upright position to avoid shattering of seeds and allowed to dry under the sun in the field. The seeds were threshed in bags on per plot basis, winnowed, cleaned, air dried and weighed to obtain the grain yield per plot and later extrapolated to yield per hectare.

All data collected were subjected to analysis of variance (ANOVA) with the help of statistical software, Statistix 8.0 [18]. The treatment means were compared using the Least Significant Difference (LSD) for the main plot and sub plot effects, while Duncan Multiple Range Test (DMRT) was used to compare their interaction effects as described by Gomez and Gomez [19]. Also, linear correlation coefficients were calculated to determine the degree of association among the sesame agronomic parameters measured.

RESULTS AND DISCUSSION

Effects of inter-row spacing and plant density on agronomic parameters

Plant height of sesame significantly ($P < 0.01$) increased at closer inter-row spacing early in the season (Table 1). The tallest plants were recorded for 25cm spacing at the early stage of growth (3 and 6 WAS), but as the growth period progressed the plant height increased significantly ($P<0.01$) with increase in spacing. By 9 WAS, the plant height was significantly higher at the 75 cm than 50 or 25 cm inter-row spacing. Katung [11] also reported that plant height increased with increasing plant population. Thus significantly shorter plants were observed at 25 cm at 9 WAS in 2006, 2007 and the combined mean. Decrease in inter-row spacing increased plant density, which probably increased competition for crop growth resources. As the season progressed, growth at the closer row spacing declined compared to the wider spacing. Ustimenko-Bakumovsky [20] reported that vigorous growth starts at bud formation till maturity of the first capsule. Olowe and Busari [12] also reported that inter-row spacing significantly affected plant height at 50% flowering and at maturity, which coincides with these growth periods. Thus competition for growth resources and crop growth stage may have influenced the trend of growth during the season.

The response of sesame to increase in plant density was almost quadratic (Table 1). The increase in plant density from 2 to 4 plants/stand significantly ($P<0.001$) increased plant height at 3 WAS in 2006. The tallest plants were observed for 4 plants per stand but plant height decreased with further increase in plant density especially at 6 and 9 WAS. Similar to the effect of row spacing, plant height significantly increased at lower plant densities than the higher densities at 9 WAS in 2007 and for the combined mean. The density of 2 plants / stand was probably low as it resulted in short plants probably due to less competition. Olowe and Busari [12] reported that the decrease in plant height at higher plant densities might be attributed to inter plant competition for space, soil moisture, nutrient, light and assimilate. Plants grown at densities higher than 4 plants / stand were relatively tall early in the season; however, values declined as the growth period progressed. This further confirms the exacerbation of plant competition due to the overstretching of growth resources at higher than the lower densities. Similar findings were reported by Odo and Dugje [21] and Dugje and Odo [22] for pearl millet and post-rainy season sorghum, respectively, in the same ecology.

The results on number of days to 50% flowering revealed that neither inter-row spacing nor plant density had significant effect in 2006 and 2007 (Table 2). However, number of days to flowering was significantly delayed at 75 cm than 25 cm for the combined mean. There was no significant difference between 25 cm and 50 cm on the one hand and between 50 cm and 75 cm on the other. Similarly, days to 50% flowering did not significantly differ among plant densities. The insignificant effect of spacing and density on 50% flowering during any year might mean that this parameter is genetically controlled.

Dry stalk weight of sesame was significantly (P<0.001) different among the inter-row spacing (Table 2). The dry stalk weight increased significantly with increase in spacing. The highest dry stalk weight was observed for the wider spacing (75 cm), while the lowest value was observed for the closer spacing (25 cm). Dry matter accumulation may have been impaired due to inadequate growth resources shared by more plants at closer than wider row spacing. This is because larger feeding area was available to the plants that were grown at wider than the closer inter rows. Olowe and Busari [3] reported similar findings that spacing of up to 90 cm enhanced dry stalk weight compared to 30 and 60 cm. Dry stalk weight was significantly (P < 0.001) higher for lower plant densities than higher densities in 2006 and 2007 (Table 2). No significant differences (P>0.05) were observed among the plant densities for the combined mean. The individual year results showed that dry stalk weight was significantly higher in 2006 than 2007.

There was significant variation (P<0.001) in seed yield per hectare in 2006 and for the combined years (Table 3). Seed yield was generally higher in 2007 than 2006 probably due to the relatively low rainfall recorded in 2006. Values were significantly higher at 50 cm spacing than 25 cm or 75 cm spacing in 2006 and slightly higher in 2007. The 75 cm spacing recorded significantly (P < 0.001) higher yield than 25 cm or 50 cm spacing for the combined mean. Thus the wider inter-rows showed more potential to realize high seed yield than the closest spacing. Increase in seed yield at wider inter-rows may be due to larger space and growth resources available per individual plant, which enhanced growth and development. The decrease in seed yield at narrow spacing could have resulted from the higher inter plant competition for growth resources.

There was significant difference in seed yield among the plant densities in 2006 and 2007. Seed yield was significantly higher for 6 plants / stand than the other plant densities in 2006. The lowest seed yields were observed for 2 and 8 plants / stand whose seed yield did not significantly differ. In 2007, 4 plants / stand significantly realized higher seed yield than the other treatments. The 2 plants / stand significantly realized the lowest seed yield compared to the other treatments in 2007 and for the combined mean. The combined seed yield was slightly higher for 4 plants / stand followed by 6, 8 and 2 plants / stand, respectively. Gupta [23] also reported that sesame seed yield per hectare increased with increasing plant density up to a maximum. The quadratic response of seed yield to increase in plant density may be explained by increase in plant population. The increase in seed yield with increase in plant density must have been accounted for by increase in the number of plants per unit area as reported by Katung [11].

Although seed weight was slightly higher at the wider inter-rows, there was no significant difference in the values observed (Table 3). Slightly higher values were obtained at 50 cm and 75 cm than 25 cm inter-rows. This further confirms the argument in support of the probability of acute plant competition for growth resources at closer inter-rows late into the growing season. Grain weights were significantly (P < 0.001) lower for 4 and 6 plants / stand in 2007 than 2 or 8 plants / stand. The superior seed yield realized at 4 and 6 stands could be attributed to moderate increases in grain weight. This is because seed weight and seed yield are mostly negatively correlated in stressful environments as observed in the present study **(**Table 6).

Interaction effects of inter-row spacing and plant density

There were significant interactions of inter-row spacing and plant density on sesame agronomic parameters **(**Table 4**)**. Plant height was significantly taller (P<0.05) at 25cm and 4 plants per stand in 2006 and 25cm with 6 plants per stand in 2007 at 3 WAS. The lowest values were observed at 75 cm with 2 plants / stand. At 6 WAS significantly higher values were recorded for 25 cm with 6 or 8 plants / stand and 75 cm with 4 plants / stand than the other treatment combinations in 2006. In 2007, plant height was significantly higher at 25 cm with 2 plants and 50 cm with 4 plants per stand than the other treatments. The values for the combined mean at 9 WAS showed significantly higher plant height for 75 cm with 4 plants / stand, which did not significantly differ from 50 cm with 2 or 4 plants / stand and 75 cm with 8 plants per stand. Thus crop growth rate was high at narrow inter-rows and high plant densities during the early stage of growth but declined as the season progressed in favour of wider rows and low plant densities which witnessed increase in plant height as the season progressed. The rapid increase in growth rate at closer spacing early in the season may have increased resource depletion as reflected in the significant decrease in plant height late into the season. The 50 cm inter-row with 4 plants per stand presented a moderate response to plant height especially at 6 and 9 WAS when the potentials for growth was almost actualized.

The number of days to 50% flowering was significantly (P < 0.05) earlier for 50 cm inter-row with 6 plants / stand than 50 cm with 4 plants per stand in 2007 (Table 4). There was no significant difference in the period of flowering of the other treatment combinations. Dry stalk weight per plant was significantly higher at 75cm with 6 and 2 or 8 plants / stand in 2006 and 2007, respectively.

Changes in the inter-row spacing were therefore the major determinant of stalk weight as values had similar trend across wide range of plant densities. Seed yields were generally low during the two years of the study. The values were relatively higher in 2007 than 2006 (Table 5). In 2006, seed yield was significantly (P< 0.001) higher for 25 cm with 6 plants per stand, which did not significantly differ from 50 cm inter- row with 4 plants per stand. However, in 2007 the 25 cm inter-row with 4 plants per stand had the highest seed yield, which was significantly (P<0.001) higher than all other interactions. The 25 cm with 2 plants per stand significantly (P<0.001) realized the lowest seed yield during both years of the study. Thus plant population density was the major determinant of seed yield given the modest increase in seed yield realized at the same inter-row spacing with changes in plant densities. The interaction of inter-row spacing and plant density on seed weight was significant (P<0.05) in 2007. The 50 cm spacing with 2 plants per stand gave the highest grain weight. This did not significantly differ from 25 cm with 8 plants per stand and 75 cm with 2

Table 1: Effects of inter-row spacing and plant density on sesame plant height (cm) at 3, 6 and 9 weeks after sowing

Treatment	3 WAS			6 WAS			9 WAS		
	2006	2007	Combined	2006	2007	Combined	2006	2007	Combined
Inter-row spacing									
25 cm×25 cm	35.60	21.39	28.50	58.44	59.00	58.72	120.5	115.2	117.9
50 cm×25 cm	26.46	21.16	23.81	49.46	58.29	53.88	131.4	131.8	131.6
75cm×25 cm	25.15	19.39	22.27	50.90	50.38	50.64	132.7	136.2	134.4
SE±	1.783	0.364	0.923	1.525	0.684	0.820	2.514	2.822	1.640
LSD(0.05)	4.951	1.011	2.562	4.235	1.900	2.277	6.981	7.835	4.552
Plant density									
2 plants/stand	23.31	20.40	21.86	47.50	59.44	53.47	125.9	135.5	130.7
4 plants/stand	33.47	21.02	27.25	57.44	55.72	56.58	134.1	135.1	134.6
6 plants/stand	28.22	20.53	24.38	52.03	54.78	53.40	124.1	115.7	119.9
8 plants/stand	31.28	20.63	25.96	54.75	53.61	54.18	128.7	124.7	126.7
SE±	1.958	0.489	5.703	1.658	1.292	2.084	1.442	1.930	2.434
LSD(0.05)	4.113	NS	NS	3.484	2.715	NS	NS	4.055	4.880
S×D interaction	*S	***S	NS	**S	**S	NS	***S	***S	**S

NS = Not Significant, * Significant (P < 0.05), ** Significant (P < 0.01), *** Significant (P < 0.001)

Table 2: Effects of inter-row spacing and plant density on number of days to 50% flowering and dry stalk weight

Treatment	Days to 50% flowering			Dry stalk weight(kg/ha)		
	2006	2007	Combined	2006	2007	Combined
Inter-rows spacing						
25 cm × 25 cm	64.75	62.25	63.50	18.38	11.16	14.77
50 cm × 25 cm	66.83	62.25	64.54	26.53	17.39	21.96
75 cm × 25 cm	68.08	62.42	65.25	36.75	29.45	33.10
SE±	1.757	1.374	0.501	0.712	0.748	0.625
LSD(0.05)	NS	NS	1.391	1.976	2.078	1.735
Plant density(D)						
2 plants/stand	67.11	62.78	64.94	23.89	23.63	23.76
4 plants/stand	66.11	62.22	64.17	24.44	22.67	23.55
6 plants/stand	66.89	62.11	64.50	29.18	11.70	20.44
8 plants/stand	66.11	62.11	64.11	31.37	19.34	25.35
SE±	0.597	0.374	1.106	0.735	1.217	2.500
LSD(0.05)	NS	NS	NS	1.544	2.556	NS
S×D interaction	NS	*S	NS	***S	***S	NS

NS = Not Significant, * Significant (P < 0.05), *** Significant (P < 0.001)

Table 3: Effects of inter-row spacing and plant density on sesame seed yield and seed weight

Treatment	Seed yield (kg/ha)			Seed weight (g)		
	2006	2007	Combined	2006	2007	Combined
Inter-row spacing						
25 cm×25 cm	109.8	452.7	281.2	14.99	12.91	13.95
50 cm×25 cm	135.2	459.0	297.1	15.18	13.42	14.30
75 cm×25 cm	91.89	436.5	364.2	15.37	13.18	14.28
SE±	1.607	8.268	4.356	0.416	0.291	0.263
LSD(0.05)	4.462	NS	12.094	NS	NS	NS
Plant density						
2 plants/stand	96.70	402.3	249.5	14.93	13.68	14.30
4 plants/stand	124.3	514.0	319.1	15.10	12.37	13.73
6 plants/stand	135.0	450.5	292.8	15.33	12.97	14.15
8 plants/stand	93.13	430.9	262.0	15.35	13.67	14.51
SE±	2.815	13.146	66.770	0.461	0.299	0.473
LSD(0.05)	5.913	27.619	NS	NS	0.629	NS
S×D interaction	***S	***S	NS	NS	*S	NS

NS = Not Significant, * Significant (P < 0.05), *** Significant (P < 0.001)

Table 4: Interaction effects of inter-row spacing and plant density on plant height (cm) at 3 WAS in 2006 and 2007, at 6 WAS in 2006 and 2007, and at 9 WAS in 2006, 2007 and combined

Inter-row spacing x Plant density	3 WAS		6 WAS		9 WAS		
	2006	2007	2006	2007	2006	2007	Combined
25 cm ×2 plants/stand	51.75^{a-d}	20.42^{bcd}	54.42^{bcd}	64.92^{a}	123.7^{de}	130.4^{cd}	127.0^{c}
25 cm ×4 plants/stand	58.50^{a}	22.09^{ab}	61.25^{a}	57.42^{cde}	123.8^{de}	121.5^{ef}	122.6^{cd}
25 cm×6 plants/stand	54.08^{abc}	23.08^{a}	57.25^{abc}	51.50^{bc}	115.8^{f}	99.08^{h}	107.5^{e}
25 cm ×8 plants/stand	58.03^{ab}	19.96^{cd}	60.83^{a}	54.17^{ef}	118.8^{ef}	109.8^{g}	114.3^{de}
50 cm ×2 plants/stand	44.83^{de}	18.92^{d}	47.67^{ef}	56.75^{cde}	132.7^{bc}	140.6^{ab}	136.6^{ab}
50 cm ×4 plants/stand	47.42^{cde}	20.88^{bc}	50.42^{def}	62.75^{ab}	132.7^{bc}	144.1^{ab}	138.4^{a}
50 cm ×6 plants/stand	43.00^{e}	22.00^{ab}	46.42^{fg}	59.00^{bcd}	126.3^{cde}	124.9^{de}	125.6^{c}
50 cm ×8 plants/stand	50.58^{bcd}	22.84^{a}	53.33^{cde}	54.67^{def}	133.8^{b}	117.8^{fg}	125.8^{c}
75 cm×2 plants/stand	33.33^{f}	21.88^{ab}	40.42^{g}	56.67^{c-f}	121.4^{ef}	135.5^{bc}	128.5^{bc}
75 cm×4 plants/stand	54.50^{abc}	20.09^{cd}	60.67^{ab}	47.00^{g}	145.8^{a}	139.6^{abc}	142.7^{a}
75 cm× 6 plants/stand	47.58^{cde}	16.50^{e}	52.42^{c-f}	45.83^{g}	130.0^{bcd}	123.1^{def}	126.5^{c}
75 cm×8 plants/stand	45.17^{de}	19.08^{cd}	50.08^{def}	52.00^{f}	133.4^{bc}	146.6^{a}	140.0^{a}
SE±	3.391	0.847	2.872	2.238	2.498	3.343	4.216

Means followed by the same letter (s) in a column are not statistically different according to Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 5: Interaction effects of inter-row spacing and plant density on days to 50% flowering, dry stalk weight, seed weight and seed yield

Inter-row spacing x Plant density	Days to 50% flowering	Dry stalk weight		Seed weight	Seed yield kg/ha	
	2007	2006	2007	2007	2006	2007
25 cm ×2 plants/stand	63.00ab	14.26f	13.95de	12.77cde	69.93g	318.6g
25 cm ×4 plants/stand	61.67ab	20.02e	13.47de	11.70e	81.47f	614.3a
25 cm×6 plants/stand	62.67ab	14.07f	5.96f	13.30bcd	182.6a	461.5bcd
25 cm ×8 plants/stand	61.67ab	25.19d	11.25e	13.87ab	105.0d	416.5def
50 cm ×2 plants/stand	62.33ab	26.72d	19.64c	14.57a	144.1b	496.9b
50 cm ×4 plants/stand	63.33a	21.87e	26.05b	12.80b-e	181.8a	432.5c-f
50 cm ×6 plants/stand	61.00b	27.19d	12.78de	13.03bcd	94.10e	476.5bc
50 cm ×8 plants/stand	62.33ab	30.34c	11.09e	13.27bcd	120.8c	430.3c-f
75 cm×2 plants/stand	63.00ab	30.70c	37.29a	13.70abc	76.07fg	391.5f
75 cm×4 plants/stand	61.67ab	31.42c	28.48b	12.60de	109.7d	495.1b
75 cm× 6 plants/stand	62.67ab	46.28a	16.36cd	12.57de	128.3c	413.5ef
75 cm×8 plants/stand	62.33ab	38.59b	35.67a	13.87abc	53.57h	445.9cde
SE±	0.648	1.273	2.108	0.518	4.875	22.770

Means followed by the same letter (s) in a column are not statistically different according to Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 6: Linear correlation coefficients (r) of sesame agronomic parameters at three row spacing and four plant density for combined mean

Parameters	1	2	3	4	5	6	7
1. Plant height 3 WAS	-	-	-	-	-	-	-
2. Plant height 6 WAS	0.05ns	-	-	-	-	-	-
3. Plant height 9 WAS	-0.01ns	0.03ns	-	-	-	-	-
4. No. of plants/plot	0.11ns	0.42***	-0.57***	-	-	-	-
5. Days to 50% flower.	0.51***	-0.38**	0.01ns	-0.27*	-	-	-
6. Dry stalk weight (kg/ha)	0.27*	-0.28*	0.62***	-0.66***	0.43***	-	-
7. Seed weight	0.68***	-0.09ns	0.07ns	-0.18ns	0.60***	0.40***	-
8. Seed yield (kg/ha)	-0.87***	0.20ns	-0.03ns	0.06ns	-0.67***	-0.40***	-0.71***

Significant ($P < 0.05$), ** Significant ($P < 0.01$), *** Significant ($P < 0.001$), Values without asterisk (s) have no significant linear correlation or 8 plants per stand. The significantly lowest seed weight was observed for 25 cm with 2 plants per stand.

Linear relationships among sesame agronomic parameters

The linear relationships among the agronomic parameters measured showed that seed yield was negatively correlated with plant height at 3 WAS (r = - 0.87***), number of days to 50% flowering (r = - 0.67***), dry stalk weight (r = - 0.40***) and seed weight (r = - 0.71***) (Table 6). Seed weight was positively correlated with plant height at 3 WAS, number of days to 50% flowering and dry stalk weight (r = 0.40*** to 0.68***). Dry stalk weight was negatively correlated with number of plants per plot (r = - 0.66***), and plant height at 6 WAS (r = - 0.28*) but positively correlated with plant height at 3 and 9 WAS (r = 0.27* to 0.62***) and number of days to 50% flowering (r = 0.43***). The major factors that contributed to decrease in seed yield at the closer row spacing and high plant densities were rapid increase in plant height early in the season, hastening of period to flowering, and increase in dry stalk seed weights. These are major characteristics that indicate the possibility of plant competition in stressful environments where rainfall and nutrients are in short supply as in the present study. The scope for improving sesame yield may not be achieved simply by increasing plant density without improving the moisture and nutrient regimes in the system. This is because the study area had very low level of N and low average annual rainfall especially in 2006 that contributed to the low seed yield realized in the present study.

CONCLUSION

The performance of sesame at closer inter-rows and higher densities was characterized by fast growth early in the season and subsequent decline as the season progressed. This trend could be attributed to increase in plant competition which is mainly associated with increase in plant density. At the closer row spacing and high plant density, seed yield was limited by inability of sesame to express optimum agronomic parameters due to plant competition. Seed yield at the wider row spacing and low plant densities was limited by low plant population and inability to compensate with yield components. Most of the parameters studied showed that the 50 cm × 25 cm spacing with 4 - 6 plants per stand (320,000 – 480,000 plants/ha) was the best combination for optimizing the agronomic performance of sesame in the study area.

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