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Response of Sesame Cultivars to Plant Density and Nitrogen in the Sudan Central Rainlands

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ABSTRACT. Field experiments were conducted for 3 years to determine the effects of cultivar, nitrogen and plant population on seed yield and other plant characteristics under the conditions of limited water supply in rainfed areas of the central Sudan. Seed yield and its components were adversely affected by delayed sowing and inadequate water supply. Cultivar, unlike nitrogen and inter-row spacing, had a significant effect on seed yield, plant height and number of capsules plant^{-1} under favourable environments (*i.e.* early sowing and adequate moisture). In the dry season, cultivars differed significantly in days to flowering whereas nitrogen significantly increased number of days to onset of flowering and increased number of capsules plant^{-1}. Cultivar x nitrogen and cultivar x spacing interactions varied with the season and the plant parameter but they were both significant for number of plant ha^{-1} in the dry and moderate seasons. Interactions of cultivar x nitrogen were also significant for seed yield in both favourable and moderate seasons and for number of capsules and plant height in the former. In the favourable environment cultivars UCR 76202 (1388 kg ha^{-1}) and UCR 75370 (979 kg ha^{-1}) had their highest seed yields (71 and 56% over the control) at 40 kg N ha^{-1}; whereas the local cultivars A/5/9 (1183 kg ha^{-1}) and A/1/9 (1057 kg ha^{-1}) had their highest yields (22 and 14% over the control) at 20 and 80 kg N ha^{-1}, respectively.

Sesame (*Sesamum indicum* L.) is one of the major oil crops in the tropics. The high amounts of protein (19-31%) and oil (40-60%) accumulated in the seed make sesame an important cash, feed and food crop in the region. Sudan, one of the main sesame producers, has been facing a recurring shortage of vegetable oil for many years due to the fluctuations in the production of oil seeds. Factors contributing to this include restriction of the cultivation of sesame to rainfed areas, lack of improved cultivars and adoption of poor cultural practices (Osman 1991).

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Investigations on cultural practices of sesame grown in rainfed areas of the tropics are scarce or mostly lacking.

Conflicting reports on the performance of sesame cultivars and their response to different levels of N and planting densities under both favourable and unfavourable environments are encountered in the literature. In this respect, Osman and Nur (1985) and Osman (1991) indicated that sesame cultivars selected from tropical x temperate crosses were more responsive to favourable environments than local (tropical) cultivars. Significant genotype x environment interactions in sesame were also reported by Henry and Daulay (1987) and by Narayanan and Narayanan (1987) in India. In this respect, Henry and Daulay (1987) identified relatively high yielding cultivars for both dry (low rains) and favourable (high rains) environments among 14 genotypes evaluated in a four year trial. In a six year yield evaluation trial, differences among cultivars, according to Narayanan and Narayanan (1987) were mostly attributable to their differential response to high population densities in the same environment.

Response of sesame to nitrogen also varied with cultivar and environment. For example, in sandy soils, foliar application of 4.6 kg N ha^{-1} (Atta and Cleemput 1988) or direct placement of 17 kg N ha^{-1} on lateritic sandy loam soils (Majumdar *et al.* 1988) or 40 kg N ha^{-1} in clay soils (Vijay *et al.* 1987) were adequate for maximizing seed yields in sesame. Increase of N rates above the 40 kg N level and up to 120 kg N ha^{-1} (Vijay *et al.* 1987) had no effect on seed yield. Such low N-requirements in sesame were confirmed by the application of labelled N-fertilizer (Atta and Cleemput 1988). Out of 238 kg N ha^{-1} applied, 74.66% (177.7 kg) were lost under the sesame field, 13.04% (31 kg) left in the soil after harvest and only 12.3% (29 kg) were recovered by the sesame plant (Atta and Cleemput 1988).

Effects of planting density on sesame yields also varied with the cultivar and the planting season. Rao *et al.* (1985) evaluated rainfed sesame under five planting densities (222, 296, 333, 444 and 666 x 10^3 plants ha^{-1}) and reported highest seed yields (880 kg ha^{-1}) at the lowest planting density. Narayanan and Narayanan (1987) evaluated six cultivars under three population densities (16, 33, and 66 x 10^3 plants ha^{-1}) and indicated that branching types gave highest yields at the intermediate density; whereas non-branching types were not significantly affected. Shekhar (1988) indicated that yields in early sown sesame were not significantly affected by inter-row spacing (20, 30 and 40 cm); whereas in late sown sesame, yields generally decreased with increased spacing.

This study was undertaken to determine the effects of season, cultivar, planting density and nitrogen application on seed yield and other plant characteristics of sesame grown under limited water supply in the central rainlands of the Sudan.

Materials and Methods

The study was conducted at Kenana Research Station in Abu Naama (12° 44' N, 34° 08' E) during the rainy seasons (June - October) of 1982, 1983 and 1984. The soils (Vertisol) of the experimental site are non-saline and have up to 70% montmorillonitic clay of pH 8.5 - 9 with free $CaCo_3$ in the profile and high total phosphate and exchangeable calcium values. Carbon is about 0.4% and total N is about 0.46 mgl^{-1}. As the onset of the effective rainy season varied from one year to another, the sowing dates for the trials also varied and consequently they were the fourth week of June, third and first week of July, respectively. The total rainfall at the experimental site in each of the three years was 540, 349 and 418 mm respectively. In the first year, five experimental cultivars [UCR 76148 (V_1) UCR 76202 (V_2), A/5/9 (V_3), A/1/9 (V_4) and UCR 75370 (V_5)] and five levels of N (0, 20, 40, 60, 80 kg N ha^{-1}) as urea were evaluated at an inter-row spacing of 75 cm as a 5 x 5 factorial experiment with four replications laid out on a randomized complete block design. In the second and third seasons, four cultivars (V_1, V_2, V_3. V_4), three levels of nitrogen (0, 40, 80 kg ha^{-1}) as subplots were randomly assigned to two inter-row spacing 60 cm (P_1) and 75 cm (P_2), as main plots in a split plot design with four replications. Of the five varieties evaluated, two (A/5/9 and A/1/9) are pure line selections from the indigenous sesame stock of the Sudan and three cultivars (UCR 76148, UCR 75370 and UCR 76202) are pure line selections from crosses between local and temperate sesame cultivars. The local cultivars are multibranching having a square (thin) stem with long internodes and one capsule leaf-$axile^{-1}$; whereas the UCR lines are non-branching, having a round (stout) stem with short internodes and three pods leaf-$axile^{-1}$.

In all seasons, seeding was done by hand by continuous placement of the seeds in small opened trenches in plots that were previously under supplementary irrigated (1982) or rainfed (1983, 1984) sorghum. In all trials, N as urea, was applied (broadcasted) two weeks after plant emergence.

Results and Discussion

Main effects

Cultivar

Seed yield of sesame was significantly affected ($P \leq 0.01$) by cultivar in the first and second seasons but not in the third (Table 1). Highest yields (758-1095 kg ha^{-1}) for all cultivars were obtained in the favourable (first) season (1982-83); whereas lowest yields (73-105 kg ha^{-1}) were obtained in the dry (second) season (1983-84) (Table 1). Similarly, Osman (1991), Osman and Nur (1985), Henry and Daulay (1987) reported that the magnitude of cultivar effect on seed yield varied with the cropping season. No doubt, early planting and adequate moisture had contributed to the high yields recorded in the first season whereas late planting and insufficient rains resulted in the low yields recorded in 1982-83. Similarly, Khalifa (1981) indicated that adequate moisture and early planting are required for achieving high yields, whereas late planting and insufficient moisture adversely affected seed yield in both sunflower (Khalifa 1981) and sesame (Osman and Nur 1985). The results also confirm those of Rao (1977) that moisture deficit especially during the reproductive phase and delayed sowing (Shekhar 1988) appreciably reduced seed yield and yield components. Reductions in seed yield under limited moisture supply as observed in this study were mostly attributed to the low N-uptake encountered under such conditions (Mackay and Barber 1986).

Table 1. Seed yield and number of plants per hectare as affected by cultivar, N-fertilizer and row spacing in rainfed sesame

	Seed yield (kg ha^{-1})			No. of plants (000 ha^{-1})		
	1982-83	**1983-84**	**1984-85**	**1982-83**	**1983-84**	**1984-85**
Treatments						
Cultivar						
V_1	758	99	344	179	152	180
V_2	1095	105	317	150	138	180
V_3	947	73	354	167	126	183
V_4	921	78	331	171	158	177
V_5	774	–	–	150	–	–
S.E. ±	44.9	19.3	4.0	20.5	9.5	3.3
N applied (kg ha^{-1})						
0	815	92	369		143	183
20	864					
40	995	93	296		145	181
60	913					
80	908	82	345		143	177
S.E. ±	44.9	16.7	21.2		8.1	4.0
Inter Row Spacing						
60 cm		82	340		157	194
75 cm		94	334		130	165
S.E. ±		13.8	13.9		13.6	11.4

Significant differences ($P \leq 0.01$) were also observed among the cultivars for both plant height and number of capsules per plant in the first season and for days to flowering in the second (Table 2). The relative ranking of the cultivars with respect to these traits, however, differed from that observed for seed yield in the different seasons, indicating that other traits (*e.g.* seed size) not included in the study might have accounted for the differences among the cultivars.

Nitrogen

Application of 40 kg N ha^{-1} in the favourable (first) season had increased seed yield from 815 to 995 kg ha^{-1} (about 22%); whereas further increase of N in this season or those between 0 and 80 kg ha^{-1} in the dry (second) and moderate (third) seasons had no significant effect on seed yield (Table 1). Application of nitrogen had

Table 2 . Plant height and number of capsules $plant^{-1}$ and days to flowering as affected by cultivar, N fertilizer and raw spacing in rainfed sesame

	Plant height (cm)		No. of capsules $plant^{-1}$		Days to flowering
	1982-83	1983-84	1982-83	1983-84	1983-84
Treatments					
Cultivar					
V_1	108	56	31	17	38
V_2	95	54	39	19	34
V_3	88	53	37	14	43
V_4	101	57	53	20	37
V_5	100	–	49	–	–
S.E. ±	2.9	3.6	2.5	1.0	0.4
N applied (kg ha^{-1})					
0	95	56	37	16	42
20	99	–	43	–	–
40	98	56	42	19	36
60	103	–	45	–	–
80	98	54	42	18	37
S.E. ±	2.9	3.1	2.5	0.8	0.3
Inter Row Spacing					
60 cm	–	55		17	38
75 cm	–	55		18	38
S.E. ±	–	1.4		0.9	0.2

also significantly ($P \leq 0.01$) increased number of capsules plant^{-1} and enhanced the onset of flowering in the dry season but had no effect on plant height (all seasons) or on number of days to the onset of flowering (second season) and number of capsules plant^{-1} in both moderate and favourable seasons (Table 2).

In previous studies, Vijay *et al.* (1987), indicated that an increase of 34% (from 730 to 980 kg ha^{-1}) in sesame yields was associated with the application of 40 kg N ha^{-1} under favourable conditions. Apparently, under the conditions of the second and third seasons, available moisture was more limiting than nitrogen. Under these dry conditions, root growth was restricted, N-influx rate at the root surface and N movement to the root surface were reduced, and consequently, N-uptake as indicated by Mackay and Barber (1986); seed yield and most of its components, as reported by Amable (1980) and Khalifa (1981) were remarkably reduced.

Planting density

Number of plants ha^{-1} was drastically reduced by the delayed sowing under the limited water supply of the second season (Table 1). Plant populations in ranges of 130,000 to 157,000 plants ha^{-1} in the dry season or those ranging from 165,000 to 194,000 in the moderate (third) season had no significant effect on seed yield (Table 1) or in any of its components (Table 2). Similarly, Shekhar (1988) reported no significant differences in yields of early sown sesame harvested from rows that were spaced 20, 30 and 40 cm apart. Other workers, (Rao *et al.* 1985, Narayanan and Narayanan 1987) reported that sesame yields - in contrast to this study - were significantly affected by planting density. This effect, according to Shekhar (1985), was more evident in late sown sesame.

Interaction effects

Cultivar x nitrogen

The cultivar x nitrogen (C x N) Interactions were significant for seed yield in the first and third seasons (Table 3), and for number of plants ha^{-1} in the second and third seasons (Table 4). Among the five cultivars evaluated: UCR 76202 and UCR 75370 at 40 kg N ha^{-1} and A/5/9 at 20 kg N ha^{-1}, in the favourable season, registered the highest seed yield ha^{-1}. These yields, being 1388, 979 and 1183 kg ha^{-1} for the respective cultivars were 41, 57 and 22%, respectively, over those recorded when no fertilizer was applied (Table 3).

Significant C x N interactions were also observed for number of days to flowering in the second season(Table 4), for number of capsules in the first (Table 5) and second

Table (3). Interaction effect of cultivar, N-fertilizer and row spacing on seed yield of rainfed sesame

Cultivar	Season 1982-83						Season 1984-85				
	V_1	V_2	V_3	V_4	V_5	Mean	V_1	V_2	V_3	V_4	Mean
Treatments					Seed yield (kg ha^{-1})						
N (kg/ha)			± 160.4		± 44.9				± 160.4		± 21.2
0	740	812	969	931	626	815	393	387	330	365	396
20	679	986	1183	710	762	864	–	–	–	–	–
40	755	1388	907	945	979	995	349	241	382	211	296
60	738	1157	919	962	788	913	–	–	–	–	–
80	879	1131	757	1057	717	908	289	324	350	418	345
			±44.9						±4.0		
Mean	758	1095	947	921	774		344	317	354	331	
Inter Row Spacing									±5.5		±13.9
60 cm	–	–	–	–	–	–	360	331	324	345	340
75 cm	–	–	–	–	–	–	326	305	386	317	334
									±4.0		
Mean (X)	–	–	–	–	–	–	343	318	355	331	

Table 4. Interaction effect of cultivar, nitrogen and row spacing on plant population (000 plant ha^{-1}) and number of days to flowering in rainfed sesame

Cultivar	V_1	V_2	V_3	V_4	Mean	V_1	V_2	V_3	V_4	Mean	V_1	V_2	V_3	V_4	Mean
Treatments															
N applied (kg ha^{-1})						No. of plants ha^{-1} (x 10^3)							Days to flowering		
		1983 - 84					1984 - 85					1983 - 84			
		± 16.4			± 8.1		± 16.2			± 4.0		± 0.6			± 0.3
0	156	117	128	172	143	186	195	186	164	183	41	36	48	37	41
40	152	148	126	152	145	163	186	192	181	181	36	34	38	35	36
80	148	149	124	151	143	191	158	172	186	177	37	32	41	38	37
		± 9.5					± 3.3					± 0.4			
Mean	152	138	126	158		180	180	183	177		38	34	42	37	
Row Spacing		± 13.3			± 13.6		± 8.8			± 11.4		± 0.5			± 0.2
60 cm	164	157	129	176	157	198	198	188	193	194	38	34	42	36	38
75cm	138	119	121	140	130	162	157	179	162	165	39	33	43	38	38
		± 9.5					± 3.3					± 0.4			
Mean	151	138	125	158		180	178	184	178		39	34	43	37	

(data not shown) seasons and for plant height in the first season. Such trends are indicative of inconsistent ranking among the cultivars for the studied traits at the different N-levels. It is also evident from this data that application of N (above 40 kg ha^{-1}) had significantly increased number of capsules $plant^{-1}$ in the local cultivar A/1/9 (Table 5); whereas that of 40 kg and above tended to induce earliness in the cultivar UCR 76202 (Table 4). Such trends indicate that under favourable environments (early crop establishment and adequate moisture) application of 40 kg N ha^{-1} are required for achieving high seed yields in cultivars similar to UCR 76202 and UCR 75370 (*i.e.* cultivars selected from crosses between tropical and temperature cultivars). It is also evident from the data that application of 20 kg N ha^{-1} or even lower rates are adequate for achieving high yields in the brown-seeded cultivar (Local: A/5/9) in the favourable season (Table 4). In previous studies, maximum seed yields in sesame were achieved on the application of 40 kg N ha^{-1} (Vijay *et al.* 1987), 17 kg N ha^{-1} (Majumdar *et al.* 1988) and at lower rates (Arunachalam and Venkatesan 1985). Unfortunately, early planting and adequate moisture are uncertain matters in rainfed areas, thus depriving the sesame grower from harvesting stable and high yields following N application. Supplementary irrigation coupled with efficient drainage system may partly alleviate this uncertainty.

Cultivar x row spacing

Interactions of cultivar x row spacing were significant for seed yield in the third season (Table 3) and for number of plants ha^{-1} in the second (data not shown) and third seasons of the trial (Table 4). All cultivars, except for UCR 76148, maintained higher seed yields at the wider spacing in the dry (second) season; whereas in the moderate (third) season the narrow spacing, except for cultivar A/5/9, resulted in significantly ($P \leq 0.01$) higher seed yields (Table 3). Differential response of sunflower cultivars (Khalifa 1981) and sesame (Narayanan and Narayanan 1987) with planting density under both favourable and unfavourable environments is reported in the literature.

Other interactions

Interactions of nitrogen with row spacing as well as those among the three factors *i.e.* V x N x P for each of the traits evaluated in the study were low and non-significant, and hence they were not presented.

Table 5. Interaction effect of cultivars nitrogen on plant height and number of capsules plant^{-1} of rainfed sesame (season 1982 - 83)

Treatment	0	20	40	60	80	Mean	0	20	40	60	80	Mean
Cultivars	plant height (cm)						No. of capsules plant^{-1}					
			± 6.5		± 2.9				± 5.6			± 2.5
V_1	85	126	110	113	105	108	23	37	32	26	35	31
V_2	103	93	94	102	82	95	49	31	41	35	37	39
V_3	80	92	82	95	93	88	32	45	37	40	31	37
V_4	117	78	103	100	105	101	39	41	53	67	68	53
V_5	88	103	103	103	104	100	39	60	46	55	46	49
			± 2.9						± 2.5			
Mean	95	99	98	103	98		37	43	42	45	42	

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استجابة أصناف السمسم للكثافة النباتية والآزوت بالمناطق المطرية الوسطى بالسودان

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درس أثر الصنف، الآزوت وعدد النباتات على الانتاجية وصفات أخرى تحت ظروف مياه محدودة لمدة ثلاث سنوات بمناطق السودان المطرية الوسطى. تأثرت الانتاجية ومكوناتها سلباً بتأخير موعد الزراعة وندرة الماء. أثر الصنف معنوياً ـ خلافاً للآزوت والمسافة بين الخطوط ـ تحت الظروف المناخية الجيدة (زراعة مبكرة ـ ومياه كافية) على طول النبات وعدد القرون بالنبات.

أما في موسم الجفاف فقد اختلفت الأصناف احصائياً في موعد الازهار بينما أدت اضافة الآزوت لزيادة معنوية في عدد الأيام لبدء الإزهار وعدد القرون بالنبات. أما التفاعلات: الصنف × الآزوت والصنف × المسافة بين الخطوط فقد اختلفت باختلاف المواسم والصفات التي درست إلا أنهما كانا معنويين لصفة عدد النبات بالهكتار خلال الموسمين المعتدل والجاف، وكذلك تفاعلات الصنف × الآزوت كانت معنوية للإنتاجية خلال الموسمين الجيد والمعتدل لعدد القرون وطول النبات خلال الموسم الجيد. وقد سجلت الأصناف UCR 76202 (١٣٨٨ كجم / هكتار) و UCR 75370 (٩٧٩ كجم / هكتار) خلال الموسم الجيد أعلى انتاجية (٥٦,٧١/ فوق المعاملة القياسية) عند معدل ٤٠ كجم آزوت للهكتار بينما سجلت الأصناف المحلية A/5/9 (١١٨٣ كجم / هكتار) و A/1/9 (١٠٥٧ كجم / هكتار) أعلى انتاجية (٢٢ و ١٤/ فوق المعاملة القياسية) عند معدل ٢٠ و ٨٠ كجم للهكتار على التوالي.

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