



RESEARCH ARTICLE

Effect of plant spacing and nutrient levels on growth and yield performance in sesame (*Sesamum indicum* L.) genotypes

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Abstract

The experiment was designed to conduct at Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, Bangalore during kharif 2021–22 and 2022–23 for 2 consecutive years to study the effect of different nutrient levels and spacing on growth and yield of sesame genotypes (*Sesamum indicum* L.). The experiment was laid out in factorial randomized complete block design having 3 factors viz., 2 genotypes (V₁: GT-1 and V₂: GKVK-1), 2 spacings (S₁: 30 × 10 cm and S₂: 45 × 10 cm) and 3 nutrient levels (F₁: 75 % recommended dose of fertiliser (RDF), F₂: 100 % RDF and F₃: 125 % RDF). The 2 years of investigation has revealed that, genotypes, GKVK-1 recorded significantly higher plant height (100.73 cm), seed yield (663 kg ha⁻¹) and oil yield (290 kg ha⁻¹). Narrow spacing of 30 × 10 cm recorded significantly higher plant height (99.22 cm), seed yield (641 kg ha⁻¹) and oil yield (282 kg ha⁻¹). Application of 125 % RDF recorded significantly higher plant height (105.08 cm), seed yield (707 kg ha⁻¹) and oil yield (313 kg ha⁻¹). Higher gross returns (₹125475 ha⁻¹), net returns (₹93820 ha⁻¹) and cost to benefit ratio (3.96) were observed in GKVK-1 genotype with spacing of 30 × 10 cm under 125 % RDF. This could be ascribed to efficient land use, better light interception and ensured nutrient supply with less competition for the resources.

Keywords: economics; genotypes; growth; nutrient; spacing; yield

Introduction

Sesame (*Sesamum indicum* L.) is a significant oilseed crop in the Pedaliaceae family, valued for its nutritional and economic benefits. It is widely cultivated in tropical and subtropical areas and is known by various names, viz., gingely, til and simsim. This ancient kharif crop typically grows to height ranging from 60–120 cm and features a branched stem. The fruit develops in capsules that mature from the bottom upward, often causing the lower pods to shatter before the upper ones fully ripen. The seeds of sesame are small and ovate. As a short-day plant, sesame flowers within 42–45 days, earning the moniker "Queen of oilseeds" due to its high-quality polyunsaturated fatty acids that are resistant to rancidity. Sesame seeds have a rich nutritional profile, comprising around 48–55 % edible oil, 20–28 % protein, 14–16 % sugars and 5–7 % minerals, along with notable antioxidant properties from compounds like sesamol and sesamin.

However, despite its many benefits, sesame production faces significant obstacles that limit both productivity and quality. The global average yield is approximately 0.46 t ha⁻¹ (1), which is considerably below its potential. Contributing factors to this low yield include inadequate fertiliser use, poor management

practices and cultivation on marginal rainfed lands. Key agricultural practices such as planting geometry and fertilisation are essential for optimising sesame yield. Effective planting geometry can improve light interception and CO₂ assimilation, while adequate mineral nutrition is crucial for higher yields. Unfortunately, many farmers, particularly in semi-arid regions, tend to use insufficient nutrients or focus on a narrow selection of fertilisers, leading to nutrient deficiencies. To overcome these challenges, it is vital to gain a comprehensive understanding of sesame's mineral nutrition requirements. The balanced application of essential nutrients like nitrogen, phosphorus and potassium is important for enhancing growth and yield. Additionally, the development of high-yielding genotypes suited for diverse agro-climatic conditions and the adoption of improved agricultural practices will be essential for boosting sesame productivity and ensuring sustainable cultivation. Among the various agro-techniques, crop geometry and nutrient management are the supreme important agronomic practices for exploring the higher yield of crops. Spacing is a very important factor to achieve higher production by better utilisation of moisture and nutrients from the soil and above ground by harvesting maximum possible solar radiation and in turn better

photosynthesis (2). With this background, current trial was undertaken with objective to find out optimum spacing required and nutrient levels to be supplied to achieve higher yield of sesame genotypes.

Materials and Methods

Study area

A field experiment was conducted during kharif 2021–22 and 2022–23 in F block, at Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. The farm is situated at 13°05' N latitude and 77°34' E longitude with an altitude of 924 m above mean sea level, comes under Eastern Dry Zone (ACZ-V) of Karnataka. The normal annual rainfall of the station was 921 mm and a major part of rain was received between May to October and maximum rainfall was received during September and October months. The normal mean minimum air temperature ranged between 14.1–20.5 °C. Whereas normal mean maximum air temperature ranged from 26.3–33.8 °C. The normal mean sunshine hours varied from 4.4–9.6 hr and normal mean monthly maximum relative humidity ranged from 77–89.0 % (Table 1).

Soil properties of experimental site

The soil of the experimental site was sandy loam in texture with consisting of 33.4 % coarse sand, 30.6 % fine sand, 6.9 % silt and 29.1 % clay. The soil found to have slightly acidic pH (5.96), low electrical conductivity (0.24 d Sm⁻¹) and low organic carbon content (0.35 %). The soil exhibited reduced level of available nitrogen (N) (260.7 kg ha⁻¹), higher phosphorus (P) (78.91 kg ha⁻¹) and moderate potassium (K) (184.21 kg ha⁻¹) (Table 2).

Experimental details

The experiment with 12 treatment combinations viz., 2 sesame genotypes (V₁: GT-1 and V₂: GKVK-1), 2 spacings (S₁: 30 × 10 cm and S₂: 45 × 10 cm) and 3 nutrient levels (F₁: 75 % recommended dose of fertiliser (RDF), F₂: 100 % RDF and F₃: 125 % RDF) were laid out in a factorial randomized complete block design and replicated thrice. Sesame genotypes GT-1 and GKVK-1 were sown with a spacing and nutrient levels according to the treatment.

Field preparation

The field preparation involved two rounds of deep ploughing using a tractor-drawn disc plough, followed by clod crushing with a cultivator and two harrowing with a blade harrow. The experiment's layout was implemented in accordance with the planned design, with individual plots tailored to the specified seed-sowing dimensions.

Manures and fertilisers

Recommended farmyard manure 5 t ha⁻¹ was applied to all the plots and incorporated well into soil 2 weeks prior to sowing. The N, P and K were applied as per the treatments through urea, di ammonium phosphate and muriate of potash at the time of sowing. The RDF for sesame is 38:25:25 kg N: P₂O₅: K₂O ha⁻¹ respectively.

Other practices

On the day of sowing 90 mL of alachlor 50 EC in 30 L of water was sprayed to all the plots. To avoid weed competition during initial crop growth stage, hand weeding was done twice at 20 DAS and 45 DAS to keep the plots weed free, one intercultural operation was carried out at 30 DAS in between the rows. Biometric observations on growth parameters were recorded at all the growth stages of crop from randomly selected 5 plants in the net plot area. Yield attributes were recorded at full maturity of the crop (at harvest). Economics was calculated based on cost incurred from the stage of field preparation up to the harvesting stage and benefit cost ratio (B:C) ratio was computed based on the income generated upon computation of yield. Plant samples were collected from the field at the time of harvesting for studying nutrient uptake. They were dried at 60 °C in hot air oven, powdered using grinder and subjected to chemical analysis to assess the removal of N, P and K. Chemical analysis of crop samples for N, P and K content was carried out using Kjeldahl method, vanadomolybdo phosphoric method and flame photometer method respectively (5).

Statistical analysis

The data collected from the experiment at different phenological growth stages were subjected to statistical analysis were inferred using standard procedures (6). Wherever the F-test was found significant for comparison among treatment means, an appropriate value of critical difference (CD) was worked out. Otherwise, the abbreviation NS (not significant) was indicated against the CD values.

Table 1. Weather parameters of experiment location

Parameters	Values
Agro-climatic zone	Eastern dry zone (ACZ-V) of Karnataka
State and district	Karnataka and Bengaluru urban
Coordinates of the site	13°05' N latitude and 77°34' E longitude
Mean annual rainfall	921 mm
Mean minimum air temperature	14.1–20.5 °C
Mean maximum air temperature	26.3–33.8 °C
Mean sunshine hours	4.4–9.6 hr
Mean monthly maximum relative humidity	77–89.0 %

Table 2. Initial physico-chemical properties of experimental site

Particulars	Values	Status	Methods employed
Coarse sand (%)	33.40	-	
Fine sand (%)	30.60	-	
Silt (%)	6.90	-	International pipette method (3)
Clay (%)	29.10	-	
Textural class	Sandy loam	-	
Soil pH (1:2.5)	5.96	Slightly acidic	Potentiometric method (3)
Electrical conductivity (1:2.5) (d Sm ⁻¹)	0.24	Low	Conductivity bridge (5)
Organic carbon (%)	0.35	Low	Walkely and Black wet oxidation method (5)
Available N (kg ha ⁻¹)	260.7	Low	Alkaline permanganate method (4)
Available P ₂ O ₅ (kg ha ⁻¹)	78.91	High	Bray's method (5)
Available K ₂ O (kg ha ⁻¹)	184.21	Medium	Flame photometer method (5)

Results

Plant height

Data on mean plant height (cm) of sesame was recorded at various stages of crop as influenced by different genotypes, planting geometry and nutrient levels, which is presented in Table 3. Average of 2 seasons data show that the genotype GKVKS-1 (81.44 cm & 100.73 cm respectively) recorded significantly higher plant height compared to GT-1 (74.43 cm & 88.20 cm respectively) both at 60 DAS and at harvest. The same results were observed in both the seasons. It may be due to varietal characteristics of sesame (7). Among spacings, narrow spacing of 30 × 10 cm (81.7 cm & 99.22 cm respectively) resulted in improved plant height compared to wider spacing of 45 × 10 cm (74.17 cm & 89.71 cm respectively). Higher plant height at closely spaced plants was mainly due to the increased competition for different resources and insufficient space for spread or low plant canopy area and energy diverted upward to increase the height instead of spreading due to lower area available to each plant and also closer spacing produces less number of branches and leaves along with less solar radiation resulting in more auxin concentration that led to increased plant height (8). Application of 125 % RDF (85.08 cm & 105.08 cm respectively) recorded significantly higher plant height compared to 75% RDF (67.44 cm & 79.85 cm respectively) and 100 % RDF (81.28 cm & 98.48 cm respectively). Fertilisers induce the growth of the plant through active protein metabolism, transportation of photosynthates and synthesis of nucleic acid and proteins. Hence,

during the vegetative stage, N nutrition of the plant largely controls the growth of the plant. Phosphorus has important role in conversion of solar energy into chemical energy and it has beneficial effect on root proliferation that increase the absorption of plant nutrients from the soil. This was obvious as phosphorus meristematic activities of the tissue in plant system are bound to increase plant height (9). Interaction values showed non-significant results for plant height in sesame genotypes. The interaction effects among different genotypes, spacing and nutrient levels were found non-significant at 60 DAS and at harvest. However, numerically higher plant height (98.56 cm & 120.43 cm respectively) was observed in GKVKS-1 genotype with spacing of 3 × 10 cm along with 125 % RDF and lower plant height (60.5 cm & 71.27 cm respectively) was observed in GT-1 genotype with 45 × 10 cm spacing along with 75 % RDF at harvest of sesame.

Number of leaves per plant

At 60 DAS and at harvest number of leaves per plant was significantly higher in GKVKS-1 genotype (82.7 & 43.63, respectively) whereas lower number of leaves was recorded in genotype GT-1 (78.14 & 38.27). This might be attributed due to genetic potential of variety that has helped in producing more number of leaves and ultimately higher leaf area (10). Planting geometry had significant effect on number of leaves. Number of leaves per plant was significantly higher in 45 × 10 cm (88.92 & 48.47 respectively) spacing. Significantly lower number of leaves recorded in 30 cm × 10 cm (71.92 & 33.44, respectively) spacing.

Table 3. Effect of spacing and different nutrient levels on growth attributes of sesame genotypes (pooled data of 2 years)

Treatments	Plant height (cm)		No. of leaves plant ⁻¹		Leaf area		Leaf area index		Dry matter production		Number of branches plant ⁻¹	
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	Harvest	
Varieties (V)												
V1: GT-1	74.43	88.20	78.14	38.27	960.83	472.80	2.61	1.15	13.60	18.92	4.69	
V2: GKVKS-1	81.44	100.73	82.70	43.63	1040.12	532.40	2.82	1.56	14.37	20.03	4.99	
F- test	*	*	*	*	*	*	*	*	*	*	*	
S. Em. ±	1.38	1.78	1.46	0.86	18.92	10.15	0.05	0.03	0.24	0.32	0.07	
C D at 5 %	4.06	5.23	4.28	2.51	55.49	29.77	0.15	0.08	0.71	0.93	0.21	
Spacing (S)												
S1: 30 cm × 10 cm	81.70	99.22	71.92	33.44	887.78	396.30	2.96	1.41	13.22	17.71	4.55	
S2: 45 cm × 10 cm	74.17	89.71	88.92	48.47	1113.17	608.90	2.47	1.30	14.74	21.24	5.13	
F- test	*	*	*	*	*	*	*	*	*	*	*	
S. Em. ±	1.38	1.78	1.46	0.86	18.92	10.15	0.05	0.03	0.24	0.32	0.07	
C D at 5 %	4.06	5.23	4.28	2.51	55.49	29.77	0.15	0.08	0.71	0.93	0.21	
Fertiliser levels (F)												
F1: 75 % RDF	67.44	79.85	73.33	32.91	883.44	415.74	2.41	1.16	13.04	17.73	4.50	
F2: 100 % RDF	81.28	98.48	80.39	40.53	984.03	476.80	2.67	1.31	13.99	19.34	4.84	
F3: 125 % RDF	85.08	105.08	87.54	49.42	1133.96	615.27	3.07	1.59	14.93	21.36	5.17	
F- test	*	*	*	*	*	*	*	*	*	*	*	
S. Em. ±	1.70	2.18	1.79	1.05	23.17	12.43	0.06	0.03	0.30	0.39	0.09	
C D at 5 %	4.97	6.41	5.24	3.08	67.96	36.46	0.18	0.10	0.87	1.14	0.25	
V × S × F												
V ₁ S ₁ F ₁	72.65	84.46	63.25	26.18	779.57	309.63	2.60	1.04	11.81	16.24	3.83	
V ₁ S ₁ F ₂	78.68	93.25	70.06	30.68	850.32	365.40	2.83	1.17	12.98	17.36	4.51	
V ₁ S ₁ F ₃	79.64	101.10	77.99	33.59	932.86	405.08	3.11	1.30	13.54	17.92	4.74	
V ₁ S ₂ F ₁	60.50	71.27	81.19	36.51	948.61	500.46	2.11	0.97	13.71	18.61	4.84	
V ₁ S ₂ F ₂	78.10	89.68	84.06	47.14	991.92	540.25	2.20	1.04	14.24	20.36	5.01	
V ₁ S ₂ F ₃	77.01	89.43	92.29	55.53	1261.69	715.98	2.80	1.35	15.29	23.04	5.21	
V ₂ S ₁ F ₁	72.81	86.56	65.74	28.79	830.52	340.14	2.77	1.41	12.64	16.56	4.40	
V ₂ S ₁ F ₂	87.86	109.53	76.99	32.48	893.28	382.46	2.98	1.52	13.50	17.60	4.67	
V ₂ S ₁ F ₃	98.56	120.43	77.49	48.89	1040.17	575.12	3.47	2.00	14.85	20.59	5.14	
V ₂ S ₂ F ₁	63.81	77.09	83.16	40.17	975.05	512.72	2.17	1.22	13.98	19.51	4.95	
V ₂ S ₂ F ₂	80.50	101.45	90.45	51.82	1200.61	619.08	2.67	1.49	15.21	22.02	5.18	
V ₂ S ₂ F ₃	85.10	109.35	102.39	59.65	1301.12	764.88	2.89	1.70	16.02	23.88	5.61	
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	
S. Em. ±	3.39	4.37	3.57	2.10	46.34	24.86	0.13	0.07	0.59	0.78	0.17	
C D at 5 %	-	-	-	-	-	-	-	-	-	-	NS	

NS: Non-significant, ** indicates significant at 5 % C D value

Availability of sufficient light and moisture to every plant at wider spacing leading to enhanced plant growth which might have led to better functional leaves per plant. Less number of leaves is mainly because of more competition between the plants for different resources in closer spacing (11). The number of leaves per plant were significantly influenced by different levels of nutrients. Significantly higher number of leaves per plant were recorded in nutrient level of 125 % (87.54 & 49.42 respectively), over 100 % (80.39 & 40.53 respectively) and 75 % (73.33 & 32.91 respectively). This might be due to the optimum nutrient levels which promotes rapid growth of stem and leaves through increased rate of photosynthesis (12). Interaction effect was non-significant at all growth stages. However, numerically it was higher in GKVKS-1 genotype with a spacing of 45 × 10 cm along with 125 % of (102.39 & 59.65, respectively) and lower in GT-1 genotype with a spacing of 30 cm × 10 cm along with 75 % RDF (63.25 & 26.18 respectively) at 60 DAS and at harvest in sesame.

Leaf area per plant

Significantly higher leaf area (1040.12 & 532.40 cm²plant⁻¹) was recorded in GKVKS-1 genotype at 60 DAS and at harvest respectively. However lower leaf area (960.83 & 472.80 cm²plant⁻¹) was found in GT-1 genotype. This might be attributed to genetic trait expression of the variety. Due to its superior genetic makeup more number of leaves are produced which in turn resulted in increasing leaf area (13). Statistically higher leaf area per plant was observed in wider spacing of 45 cm × 10 cm at harvest (1113.17 & 608.90 cm² plant⁻¹) compared to narrow spacing of 30 × 10 cm (887.78 & 396.30 cm² plant⁻¹) at 60 DAS and at harvest respectively. This might be due to the sufficient availability of nutrients, space, sunlight and soil moisture which leads to more number of leaves and broader leaves resulted in higher leaf area under wider spacing and availability of lateral spaces for side branch production with ideal geometrical arrangement could have increased the number of branches per plant there by more number of functional leaves and ultimately leaf area per plant (14). Application of 125 % RDF recorded significantly higher leaf area (1133.96 & 615.27 cm² plant⁻¹, respectively) followed by 100 % (984.03 & 476.80 cm² plant⁻¹, respectively). Plant with sufficient nitrogen will experience high rates of photosynthesis and exhibit vigorous plant growth and development. Hence leaf area will increase in such plants (15–17). Interaction effects were found non-significant. However, it was numerically more (1301.12 & 764.88 cm² plant⁻¹) in GKVKS-1 genotype with a spacing of 45 × 10 cm along with 125 % RDF and lower (779.57 & 309.63 cm² plant⁻¹) in GT-1 genotype in 30 cm × 10 cm spacing along with 75 % RDF at 60 DAS and at harvest respectively.

Leaf area index (LAI)

At 60 DAS and at harvest genotype GKVKS-1 recorded significantly higher leaf area index (LAI) (2.82 and 1.56, respectively), compared to GT-1 (2.61 and 1.15 respectively). Similar results indicating significant differences in LAI among cultivars were reported (18). At 60 DAS and at harvest spacing of 30 × 10 cm recorded significantly higher LAI (2.96 and 1.41, respectively) compared to wider spacing of 45 × 10 cm (2.47 and 1.30, respectively). Application of higher levels of nutrients i.e. 125 % of RDF resulted in significantly higher LAI at 60 DAS and at harvest (3.07 and 1.59 respectively), whereas significantly lower LAI was recorded in 75 % RDF (2.41 and 1.16 respectively) (19, 20). Interaction effects were found non-significant for LAI at 60 DAS and at harvest. However, numerically it was

noticed higher in genotype GKVKS-1 under spacing of 30 cm × 10 cm along with 125 % RDF (3.47 & 2.00) and lower in genotype GT-1 under spacing of 45 × 10 cm along with 75 % RDF (2.11 & 0.97) at 60 DAS and at harvest respectively.

Total dry matter production

Among 2 genotypes, GKVKS-1 recorded significantly higher plant dry matter (14.37 & 20.03 g plant⁻¹ respectively) compared to GT-1 both at 60 DAS and at harvest. Genotype GKVKS-1 produced more dry matter as compared to genotype GT-1 at all the stages of crop growth and at harvest due to more number of branches, functional leaves and number of capsules plant⁻¹ i.e. higher biomass potential. Such differential dry matter production in different sesame varieties was observed (21). Different planting geometry has influenced accumulation of plant dry matter significantly. Spacing of 45 × 10 cm recorded significantly higher plant dry matter accumulation (14.74 & 21.24 g plant⁻¹, respectively) compared to spacing of 30 × 10 cm (13.22 & 17.71 g plant⁻¹). Thus, the increased total dry matter per plant under wider spacing which usually associated with increased leaf area per plant has led to greater accumulation of photosynthates. Due to wider spacing (45 × 15 cm) better availability of light, nutrient and moisture, which facilitated better performance of individual plants to produce more number of branches, number of leaves and leaf area. In turn, more photosynthesis and subsequent accumulation in stem and finally increased in total dry matter per plant (22, 23). Significant changes in dry matter accumulation were observed with different nutrient levels. Plant dry matter accumulation was significantly more (14.93 & 21.36 g plant⁻¹) at % RDF over 100 and 75 % RDF. These results might be associated with more number of leaves and branches with increased absorption of nutrients at all stages of growth that enhanced the rate of dry matter production (24, 25). Interaction effects showed non-significant. However, at 60 DAS and at harvest numerically higher plant dry matter (16.02 & 23.88 g plant⁻¹, respectively) was observed in GKVKS-1 genotype with spacing of 45 × 10 cm along with application of 125 % of RDF and lower plant dry matter (11.81 & 16.24 g plant⁻¹, respectively) in GT-1 with spacing of 30 × 10 cm along with application of 75 % RDF.

Number of branches per plant

Among the genotypes, GKVKS-1 has recorded significantly higher number branches (4.99 plant⁻¹) compared to GT-1 (4.69 plant⁻¹). The differences in number of branches could be attributed to their genetic constitutions of varieties (26, 27). Number of branches per plant were significantly affected by planting geometry at harvest. Wider spacing of 45 × 10 cm has recorded significantly higher number of branches (5.13 plant⁻¹) compared to narrow spacing of 30 × 10 cm (4.55 plant⁻¹). This might be due to maximum expression of vegetative growth in wider spacing under cumulative effect of increased unit area and space for the development of branches and comparative decrease in number of branches at closer spacing may be due to more competition for light, space and nutrients among the plants, which resulted in vertical growth of the plant rather than horizontal growth (28–30). RDF of 125 % recorded significantly higher number of branches (5.17 plant⁻¹), compared to 100 % RDF (4.84 plant⁻¹) and 75 % RDF (4.50 plant⁻¹). Number of branches were improved with higher level of fertilizer application in sesame by improving vegetative growth and better absorption of nutrients (31, 32). Interaction effects due to different genotypes, planting geometry and nutrient levels were

found non-significant. Numerically higher number of branches (5.75 plant^{-1}) were observed in GKVKS-1 genotype under spacing of $45 \times 10 \text{ cm}$ along with 125 % RDF and lower (3.99 plant^{-1}) in GT-1 genotype under spacing of $30 \times 10 \text{ cm}$ along with 75 % RDF.

Number of capsules per plant

Among the sesame genotypes, GKVKS-1 has recorded significantly higher number of capsules (45.17 plant^{-1}) at harvest. However, genotype GT-1 has recorded significantly lower number of capsules (41.33 plant^{-1}) at harvest. The better development of the plants in terms of plant height, number of branches and dry biomass production leading to increased bearing capacity of these varieties. The differences in number of capsules per plant of these varieties could be attributed to their genetic constitution (33). The number of capsules per plant of sesame at harvest were significantly higher with spacing of $45 \times 10 \text{ cm}$ (48.75 plant^{-1}). Whereas, spacing of $30 \times 10 \text{ cm}$ has recorded significantly lower number of capsules (37.75 plant^{-1}). This might be due to wider spacing encourages more number of branches leading to produce more number of capsules. Varied levels of nutrients had also shown significant difference among the number of capsules per plant of sesame at harvest. The maximum number of capsules per plant (49.38) was obtained from application of 125 % RDF, compared to 100 % RDF (42.50) and 75 % RDF (37.88). Improvement in number of capsules with higher nutrient levels may be due to more vegetative growth and increased plant metabolic activities contributed to better carbohydrates assimilation and translocation of photosynthates towards developing flowers there by increased number of capsules per plant. It was also due to more dry matter production with appropriate nutrient application transferred into more per cent of capsules per plant (34). However, interaction effects found statistically non-significant due to different genotypes, spacing and nutrient levels for capsules per plant in sesame. Numerically more (57.00) in genotype GKVKS-1 with a spacing of $45 \text{ cm} \times 10 \text{ cm}$ along with application of 125 % of RDF and lower (34.00) was recorded in genotype GT-1 with a spacing of $30 \times 10 \text{ cm}$ along with application of 75 % RDF.

Number of seeds per capsule

Among different sesame genotypes, GKVKS-1 has recorded significantly maximum number of seeds per capsule (61.68) at harvest. Whereas significantly minimum number of seeds per capsule (58.33) at harvest were recorded in GT-1 genotype. For different spacing levels, number of seeds per capsule at harvest were found statistically significant. Wider spacing of $45 \times 10 \text{ cm}$ recorded significantly maximum number of seeds per capsule (63.97) and minimum in $30 \times 10 \text{ cm}$ (56.03). This can be achieved with optimum plant density, which not only utilises moisture and nutrient more effectively but also avoids intra plant competition among the plant (32). Nutrient levels showed significant difference for number of seeds per capsule in sesame at harvest. Significantly maximum number of seeds per capsule were recorded in 125 % of RDF (64.33), followed by 100 % RDF (60.15). Whereas minimum number of seeds per capsule (55.53) were observed in 75 % RDF (35). However, interaction effects found statistically non-significant. Numerically maximum number of seeds per capsule (68.58) were observed in genotype GKVKS-1 with a spacing of $45 \times 10 \text{ cm}$ along with 125 % RDF and minimum (50.47) in GT-1 genotype with a spacing of $30 \times 10 \text{ cm}$ along with 75 % RDF.

Seed weight per capsule

Seed weight per capsule in sesame was statistically influenced by different genotypes. At harvest genotype GKVKS-1 recorded significantly higher seed weight per capsule (0.14 g) and lower seed weight per capsule (0.12 g) was recorded in genotype GT-1. The results of different planting geometry on number of seeds per capsule of sesame at harvest was found significant. Wider spacing of $45 \times 10 \text{ cm}$ recorded significantly higher seed weight per capsule (0.14 g) compared to $30 \times 10 \text{ cm}$ spacing (0.12 g). This might be due to higher rate of photosynthesis and proper translocation of photosynthates from source to sink by the availability of sufficient space for growth (36). Nutrient levels showed significant difference for seed weight per capsule in sesame at harvest. Application of 125 % of RDF recorded significantly higher seed weight per capsule (0.14 g), followed by 100 % of RDF (0.13 g). Whereas significantly lower seed weight per capsule (0.12 g) was recorded in application of 75 % of RDF. This might be due to increased growth parameters and optimum dry matter translocation to the desired plant part which could be able to achieve high seed weight per capsule (37). However, interaction effects found statistically non-significant due to different genotypes, spacing and nutrient levels for seed weight per capsule in sesame at harvest. Numerically higher seed weight per capsule (0.17 g) was observed in genotype GKVKS-1 with a spacing of $45 \times 10 \text{ cm}$ along with 125 % RDF and minimum (0.11 g) in GT-1 genotype with a spacing of $30 \times 10 \text{ cm}$ along with 75 % RDF.

Seed weight per plant

Seed weight per plant varied significantly among sesame genotypes at harvest. Genotype GKVKS-1 recorded significantly higher seed weight ($5.15 \text{ g plant}^{-1}$). Spacing of $45 \times 10 \text{ cm}$ gave significantly higher seed weight ($5.38 \text{ g plant}^{-1}$). Whereas significantly lower seed weight ($4.86 \text{ g plant}^{-1}$) was recorded in GT-1 genotype. Significantly lower seed weight per plant was recorded in spacing of $30 \text{ cm} \times 10 \text{ cm}$ ($4.63 \text{ g plant}^{-1}$). The increase in seed weight per plant might be due to the cumulative effect of number of capsules per plant, number of seeds per capsule and test weight. Increasing trend of seed weight per plant was observed with the wider spacing due to more space and nutrient availability for development of more number of branches lead to more number of capsules per plant (38). Application of 125 % RDF produced significantly higher seed weight ($5.41 \text{ g plant}^{-1}$), compared to 100 % RDF ($4.99 \text{ g plant}^{-1}$) and 75 % RDF ($4.61 \text{ g plant}^{-1}$). However, interaction effects found statistically non-significant. Numerically higher seed weight ($5.79 \text{ g plant}^{-1}$) was observed in genotype GKVKS-1 with a spacing of $45 \times 10 \text{ cm}$ along with 125 % RDF and lower ($4.14 \text{ g plant}^{-1}$) in GT-1 genotype with a spacing of $30 \times 10 \text{ cm}$ along with 75 % RDF.

Test weight (g)

Test weight of sesame was found non-significant among the different sesame genotypes. However, GKVKS-1 genotype recorded numerically higher test weight (2.93 g) and lowest (2.86 g) in GT-1 genotype. The results of different planting geometry on test weight of sesame were found non-significant. However, numerically it had higher for $45 \times 10 \text{ cm}$ spacing (2.98 g) and lowest (2.83 g) in $30 \times 10 \text{ cm}$ spacing level. Neither row nor plant spacing affected the test weight of sesame seed (39). Different levels of nutrients showed non-significant in test weight of sesame. However, numerically higher test weight of sesame was recorded under 125 % RDF (2.99 g), over 100 % RDF (2.90 g) and 75 % RDF

(2.80 g). The combination result of different sesame genotypes, crop geometry and RDF levels found non-significant. Among the different combinations genotype GKVKS-1 with spacing of 45 × 10 cm under 125 % RDF (3.10 g) gave higher test weight whereas, the lower test weight was recorded in GT-1 genotype with spacing of 30 × 10 cm under 75 % RDF (2.80 g).

Seed yield

Influence of different sesame genotypes, crop geometry, nutrients levels and their interaction on the seed yield (kg ha⁻¹) of sesame is presented in Table 4. Among the different sesame genotypes, GKVKS-1 has recorded significantly higher seed yield (663 kg ha⁻¹) compared to GT-1 (562 kg ha⁻¹). This increase in seed yield of genotype GKVKS-1 might be due to higher production efficiency which was reflected through improvement in different yield contributing characters and genetical efficiency of the genotype to convert biological yield into economic yield (38). Results revealed that significantly higher seed yield was recorded with the spacing of 30 × 10 cm (641 kg ha⁻¹) and compared to 45 × 10 cm spacing (584 kg ha⁻¹). Increase in seed yield in closer spacing was due to significant increase in plant population per unit area which compensated the seed yield even though there were lesser number of capsules per plant, number of seeds per capsule and seed weight per plant. Lower plant population at 45 cm × 10 cm spacing was major cause for its reduced seed yield per hectare after achieving higher yield attributing parameters. These results are in conformity with results obtained in a previous study (40). Application of 125 % RDF had recorded

significantly higher seed yield (707 kg ha⁻¹) compared to 100 % RDF (664 kg ha⁻¹) and 75 % RDF (467 kg ha⁻¹). Optimum increase in nutrient levels increases both growth and yield attributing characters which in turn increases seed yield. The interaction effects were found statistically non-significant for seed yield of sesame. Combination of GKVKS-1 genotype under spacing of 30 × 10 cm along with application of 125 % RDF recorded numerically higher seed yield (837 kg ha⁻¹). The lower seed yield (433 kg ha⁻¹) was recorded in GT-1 genotype under spacing of 45 × 10 cm along with application of 75 % RDF.

Stalk yield

Stalk yield varied significantly among genotypes, crop geometry and nutrient levels. Genotype GKVKS-1 (1744 kg ha⁻¹) produced significantly higher stalk yield compared to GT-1 (1548 kg ha⁻¹). The spacing of 30 × 10 cm recorded significantly higher stalk yield (1738 kg ha⁻¹) over spacing of 45 × 10 cm (1554 kg ha⁻¹). This might be due to increased plant population per unit area in narrow spacing along with increased plant height of the crop contributed higher stalk yield. Application of 125 % RDF (1887 kg ha⁻¹) recorded higher stalk yield compared to 100 and 75 % RDF (1755 & 1297 kg ha⁻¹, respectively). The interaction effects were found statistically non-significant for seed and stalk yield of sesame. Numerically higher stalk yield (2136 kg ha⁻¹) was observed in GKVKS-1 genotype under spacing of 30 cm × 10 cm along with application of 125 % RDF. The lower stalk yield was recorded in GT-1 genotype under spacing of 45 × 10 cm along with application of 75 % RDF (1184 kg ha⁻¹).

Table 4. Effect of spacing and different nutrient levels on yield parameters of sesame genotypes (pooled data of 2 years)

Treatments	No. of capsules plant ⁻¹	No. of seeds capsule ⁻¹	Seed weight capsule ⁻¹	Test Weight (g)	Seed weight plant ⁻¹	Seed yield (kg ha ⁻¹)	Stalk Yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)
Varieties (V)								
V ₁ : GT-1	41.33	58.33	0.12	2.86	4.86	562	1548	2110
V ₂ : GKVKS-1	45.17	61.68	0.14	2.93	5.15	663	1744	2408
F- test	*	*	*	NS	*	*	*	*
S. Em. ±	0.81	1.12	0.002	0.05	0.09	11	31	41
C D at 5 %	2.37	3.28	0.007	-	0.27	31	91	120
Spacing (S)								
S ₁ : 30 cm × 10 cm	37.75	56.03	0.12	2.82	4.63	641	1738	2380
S ₂ : 45 cm × 10 cm	48.75	63.97	0.14	2.98	5.38	584	1554	2138
F- test	*	*	*	NS	*	*	*	*
S. Em. ±	0.81	1.12	0.002	0.05	0.09	11	31	41
C D at 5 %	2.37	3.28	0.007	-	0.27	31	91	120
Fertilizer levels (F)								
F ₁ : 75 % RDF	37.88	55.53	0.12	2.80	4.61	467	1297	1764
F ₂ : 100 % RDF	42.50	60.15	0.13	2.90	4.99	664	1755	2419
F ₃ : 125 % RDF	49.38	64.33	0.14	2.99	5.41	707	1887	2594
F- test	*	*	*	NS	*	*	*	*
S. Em. ±	0.99	1.37	0.003	0.07	0.11	13	38	50
C D at 5 %	2.90	4.02	0.009	-	0.33	38	112	147
V × S × F								
V ₁ S ₁ F ₁	32.00	50.47	0.11	2.63	4.14	455	1338	1792.00
V ₁ S ₁ F ₂	34.50	55.46	0.11	2.82	4.46	631	1672	2303.00
V ₁ S ₁ F ₃	40.00	56.48	0.12	2.88	4.74	676	1919	2595.00
V ₁ S ₂ F ₁	42.00	57.61	0.12	2.90	4.84	433	1184	1617.00
V ₁ S ₂ F ₂	46.50	62.52	0.13	2.94	5.34	584	1538	2121.50
V ₁ S ₂ F ₃	53.00	67.43	0.15	3.03	5.65	592	1640	2232.00
V ₂ S ₁ F ₁	33.50	52.80	0.11	2.75	4.36	510	1392	1901.50
V ₂ S ₁ F ₂	37.50	56.18	0.12	2.86	4.59	739	1975	2713.50
V ₂ S ₁ F ₃	49.00	64.83	0.13	2.97	5.48	837	2136	2972.00
V ₂ S ₂ F ₁	44.00	61.27	0.13	2.92	5.09	470	1274	1744.00
V ₂ S ₂ F ₂	51.50	66.43	0.15	2.99	5.58	703	1837	2539.00
V ₂ S ₂ F ₃	55.50	68.58	0.17	3.10	5.79	723	1853	2575.50
F- test	NS	NS	-	NS	NS	NS	NS	NS
S. Em. ±	1.98	2.74	0.006	0.13	0.23	26	76	100
C D at 5 %	-	-	NS	-	-	-	-	-

NS: Non-significant, ** indicates significant at 5 % C D value.

Biological yield

GKVK-1 has recorded significantly higher biological yield (2488 kg ha⁻¹) compared to GT-1 (2166 kg ha⁻¹). This might be attributed to accumulation of more dry matter and higher biomass potential. Results revealed that significantly higher biological yield was recorded with the spacing of 30 cm × 10 cm (2446 kg ha⁻¹) over 45 cm × 10 cm spacing (2207 kg ha⁻¹). This might be due to increased plant population per unit area could be the reason for realising higher biological yield under 30 cm × 10 cm. Application of 125 % RDF had recorded significantly higher biological yield (2673 kg ha⁻¹) over 100 % RDF (2496 kg ha⁻¹) and 75 % RDF (1862 kg ha⁻¹). For different sesame genotypes, planting geometry and nutrient levels interaction effect was found to be non-significant for biological yield of sesame. For different sesame genotypes, planting geometry and nutrient levels interaction effect was found to be non-significant for biological yield of sesame. Combination of GKVK-1 genotype under spacing of 30 cm × 10 cm along with application of 125 % RDF recorded numerically higher biological yield (2972 kg ha⁻¹) whereas, the lower biological yield (1617 kg ha⁻¹) was recorded in GT-1 genotype under spacing of 45 cm × 10 cm along with application of 75 % RDF.

Oil yield (kg ha⁻¹)

Average of 2 years data on oil yield was presented in Fig. 1. Among various treatment combinations no significant difference was seen for oil yield. Numerically higher oil yield (365 kg ha⁻¹) was obtained by growing GKVK-1 genotype with narrow spacing of 30 cm × 10 cm and application of 125 % RDF followed by combination of

GKVK-1 with spacing of 30 cm × 10 cm and application of 100 % RDF (323 kg ha⁻¹). This might be due to the increased plant population per unit area which compensated the yield and yield attributing characters under narrow spacing (41). The balanced optimum level nutrient application through inorganic fertiliser increased oil content and oil production and due to higher seed yield received from higher dose of NPK resulted in higher oil yield (42). But combination of genotype GT-1 with wider spacing of 45 × 10 cm and fertilisation of 75 % RDF recorded lower yield (191 kg ha⁻¹) among all the combinations.

Oil content (%)

Influence of 12 treatment combinations on seed oil content was estimated and presented in Fig. 1. Interaction effects found statistically non-significant due to different genotypes, spacing and nutrient levels for seed oil content of sesame seeds. Numerically higher seed oil content (44.96 %) was observed in genotype GT-1 with a spacing of 45 cm × 10 cm along with 125 % RDF and lower (43.49 %) in GKVK-1 genotype with a spacing of 30 cm × 10 cm along with 75 % RDF. Present results are in conformity with earlier findings (43, 44).

Economics

Economics of sesame as influenced by different genotypes, crop geometry and nutrient levels is presented in Table 5. Here influence of 12 treatment combinations on economics was calculated. Higher cost of cultivation was found in both V₂S₁F₃ and V₁S₁F₃ (₹31655 ha⁻¹) treatment combinations compared to other treatments. The higher gross return was obtained in GKVK-1

Table 5. Economics of sesame genotypes as influenced by spacing and nutrient levels (pooled data of 2 years)

Treatment combinations	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B:C
V ₁ S ₁ F ₁	31036	68175	37139	2.20
V ₁ S ₁ F ₂	31346	94650	63304	3.02
V ₁ S ₁ F ₃	31655	101400	69745	3.20
V ₁ S ₂ F ₁	30786	64950	34164	2.11
V ₁ S ₂ F ₂	31096	87600	56504	2.82
V ₁ S ₂ F ₃	31405	88800	57395	2.83
V ₂ S ₁ F ₁	31036	76425	45389	2.46
V ₂ S ₁ F ₂	31346	110850	79504	3.54
V ₂ S ₁ F ₃	31655	125475	93820	3.96
V ₂ S ₂ F ₁	30786	70500	39714	2.29
V ₂ S ₂ F ₂	31096	105375	74279	3.39
V ₂ S ₂ F ₃	31405	108375	76970	3.45

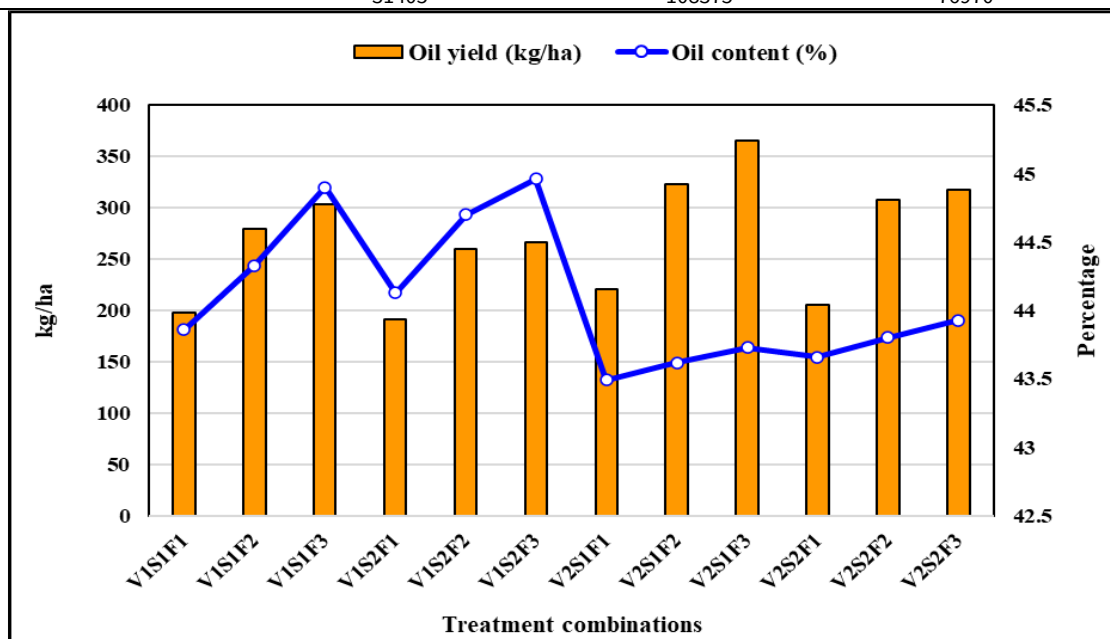


Fig. 1. Oil content and oil yield of sesame genotypes as influenced by different spacing and nutrient levels (pooled data of 2 years).

genotype with spacing of 30 × 10 cm under 125 % RDF (₹125475 ha⁻¹) and lower gross return was observed in genotype GT-1 with spacing of 45 × 10 cm under 75 % RDF (₹64950 ha⁻¹). Higher net return was observed in GKVKS-1 genotype with spacing of 30 × 10 cm under 125 % RDF (₹93820 ha⁻¹) and lower net return was observed in genotype GT-1 with spacing of 45 × 10 cm under 75 % RDF (₹34164 ha⁻¹). Higher profit was observed in GKVKS-1 genotype with spacing of 30 × 10 cm under 125 % RDF. This was mainly due to effective utilisation of available resources resulted in higher growth and yield attributes in narrow spacing of sesame. The increased return was due to higher seed yield which was resultant of better utilization of nutrients in adequate quantities. Benefit cost ratio was found to be higher in V₂S₁F₃(3.96) compared to other combinations. This may be due to higher yield of sesame in this treatment which resulted in the higher net returns which made increase in the B:C ratio compared to others.

Conclusion

From the above 2 years investigation, it is evident that varietal characteristics, planting geometry and nutrient levels had significant impact on growth and yield attributes of sesame crop. Cultivation of GKVKS-1 genotype with narrow spacing of 30 × 10 cm followed by application of 125 % RDF resulted in improvement in all the growth characteristics and yield attributes which further complimented for significant increase in seed and oil yield of sesame. As it is important oilseed crop of the country there is lot of scope for agronomic investigation for exploiting its yielding potential in different agroclimatic conditions of country.

Authors' contributions

ZKP carried out the field experiment and manuscript writing, PK, KR, GS, TT, GKN and RP contributed to statistical analysis and manuscript writing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

- India. Directorate of Economics and Statistics. Agricultural statistical information. New Delhi; 2018. p. 1-519.
- Aliveni A, Venkateshwarlu B, Sreerekha M, Prasad PRK, Jayalalitha K. Influence of crop geometry and nutrient management practices on productivity of finger millet: A review. *J Pharmacogn Phytochem*. 2020;9(4):1143-6.
- Piper CS. Soil and plant analysis. New York: Inter Science Publishers Inc.; 1966.
- Subbiah BV, Asija GL. A rapid procedure for determination of available nitrogen in soil. *Curr Sci*. 1956;25:259-60.
- Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt Ltd; 1967. p. 498.
- Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley and Sons; 1984.
- Shaikh MF, Mirza IB, Shaikh SN. Performance of niger (*Guizotia abyssinica*) varieties under varied weather condition of Marathwada region. *Indian J Pure Appl Biosci*. 2019;7(4):473-7. <https://doi.org/10.18782/2320-7051.7742>
- Kivadasannavar, Deshpande VK, Vykaranahal BS. Effect of sowing time, plant geometry and fungicidal spray on crop growth and seed yield of niger. *Karnataka J Agric Sci*. 2007;20(4):848-50.
- Singh SR, Singh U, Singh JK. Effect of bioinoculants and farmyard manure on growth, yield and quality of soybean (*Glycine max*) under rainfed conditions of Kashmir valley. *Ann Agric Res New Ser*. 2009;30(4):87-90.
- Gokhale DN, Bavalgave VG, Waghmare MS, Khandekar BS. Performance of sesamum (*Sesamum indicum* L.) genotype to varying plant densities. *Int J Agric Sci*. 2009;5(1):226-8.
- Yadav N, Tiwari OP, Shrivastava GK. Response of spring sunflower (*Helianthus annuus*) to nitrogen and row plant geometry with different intercrops for rice fallows of eastern Madhya Pradesh. *J Oilseeds Res*. 1998;15(2):377-8.
- Kumar V, Subbian MP, Lourduraj AC, Selvaraju R, Ramesh S. Effect of split application of nitrogen and interaction effect of nitrogen and plant population on growth and yield of sunflower. *Agric Rev*. 2003;24(4):303-7.
- Nirmala VS, Gopalan A, Sassikumar D. Correlation and path coefficient analysis in sunflower (*Helianthus annuus* L.). *Madras Agric J*. 2000;86(6):269-72. <https://doi.org/10.29321/MAJ.10.A00598>
- Panneerselvam PR, Isaac M, Hussain BJ. Evaluation of different varieties of sesame with different spacing under rice fallow conditions. *Sesame Safflower Newsl*. 2005;19:62-6.
- Jadhav SG, Kalegore NK, Chavan DA, Shaikh FG, Dadgale PR. Productivity of soybean (*Glycine max*) in relation to cultivars and graded levels of nutrients. *J Oilseed Res*. 2012;29(1):104-5.
- Ambika V, Yadahalli GS, Chittapur BM, Kulkarni S, Yadahalli VG, Malakannavar S. Influence of land configurations and nutrient levels on growth, yield and economics of Bt cotton. *Int J Curr Microbiol Appl Sci*. 2017;6(12):3095-102. <https://doi.org/10.20546/ijcmas.2017.612.361>
- Sandeep KR, Kubsad VS. Growth and yield of niger (*Guizotia abyssinica* L. Cass.) as influenced by planting geometry, fertilizer levels and cycocel spray. *J Farm Sci*. 2020;30(2):172-6.
- Das TK. Studies on the performance of some new mustard genotypes under irrigated condition. *J Oilseeds Res*. 1998;15:310-14.
- Paikaray RK, Misra RC, Sahu PK, Panda BS. Response of niger varieties to levels of fertility. *Orissa J Agric Res*. 1990;8(4):21-6.
- Trivedi SJ, Ahlawat RPS. Effect of nitrogen and phosphorus on growth and yield on niger (*Guizotia abyssinica* Cass). *Indian J Agron*. 1991;36(3):432-3.
- Subrahmaniyan K, Arulmozhi N. Response of sesame (*Sesamum indicum* L.) to plant population and nitrogen under irrigated condition. *Indian J Agron*. 1999;44(2):413-15. <https://doi.org/10.59797/ija.v44i2.3526>
- Patra AK, Mishra A. Effect of variety, nitrogen and spacing on yield attributes and yield of sesame (*Sesamum indicum* L.) during post rainy season. *J Oilseeds Res*. 2000;17(1):113-16.
- Majumdar DK, Roy SK. Response of summer sesame (*Sesamum indicum* L.) to irrigation, row spacing and plant population. *Indian J Agron*. 1992;37(4):758-62.
- Misra LD, Sahu SK, Rao SV. Response of niger to dose and mode of application of nitrogen. *J Oilseeds Res*. 1982;14:101-2.
- Thakuria K, Gogoi PK. Nutrient requirement of niger (*Guizotia abyssinica*) under rainfed condition. *Indian J Agron*. 1992;37(3):608-10.
- Thakur BD, Borulkar DN. Effect of spacing and nitrogen levels on growth, yield and quality of different varieties of sesamum (*Sesamum indicum* L.). *J Oilseeds Res*. 1980;85-7.

27. Kumaresani D, Nadarajan N. Stability analysis for yields and its components in sesame (*Sesamum indicum* L.). Indian J Agric Res. 2000;39(1):60–3.
28. Singh, Verma SNP. Yield potential of niger. Mysore J Agric Sci. 1975;9(4):644–8.
29. Singh PP, Nakhtore CL, Motiramani DP. Yield potential of some niger varieties as influenced by sowing time and row spacing. Mysore J Agric Sci. 1982;16:392–5.
30. Paikaray RK, Mishra KN, Khanda CM, Garnayak LM. Effect of nitrogen, phosphorus and plant density on yield and nutrient uptake in late sown niger (*Guizotia abyssinica*). Indian J Agron. 1997;42(3):520–3.
31. Thakur NS, Deshmukh MR, Sharma RS. Studies on N and P fertilization of niger (*Guizotia abyssinica* Cass) in Satpura Plateau Zone of Madhya Pradesh. J Oilseed Res. 2005;22(1):213–14.
32. Patel KS, Patel GN, Patel HC, Pathak HC, Patel JK. Nitrogen requirement of rabi castor (*Ricinus communis* L.) under different crop sequences. J Oilseed Res. 2005;22(1):209–10.
33. Basavaraj B, Shetty RA, Hunshal CS. Response of sesame varieties to fertilizer and population levels in paddy lands of Tunga Bhadra Project Area during summer. Karnataka J Agric Sci. 2000;13(1):138–40.
34. Prasannakumara BM, Chittapur BM, Hiremath SM, Malligwad LH, Nadaf HL, Koti RV. Effect of fertilizer levels and planting geometry on the performance of sesame (*Sesamum indicum* L.) genotypes. Karnataka J Agric Sci. 2014;27(3):289–92.
35. Agarwal KK, Jain KK, Sharma RS, Kashyap ML. Response of winter niger (*Guizotia abyssinica* Cass) to sowing time and fertility levels. J Oilseeds Res. 1996;13(1):122–3.
36. Uke PS, Pasalawar AN, Wakode MM, Deshmukh AB, Deshmukh SN. Effect of plant density on productivity of new safflower genotypes. J Oilseed Res. 2009;26:310–11.
37. Jakusko BB, Usman BD, Mustapha AB. Studies on the effect of plant density on growth and yield of sesame (*Sesamum indicum* L.) in Yola, Adamawa State, Nigeria. J Agric Vet Sci. 2013;5:36–9. <https://doi.org/10.9790/2380-0233639>
38. Malik NA, Arugh OH, Ramzan M. Effect of row spacing and fertility levels on quantity and quality of sesame (*Sesamum indicum* L.). Indian J Agric Sci. 1992;30(2):213–19.
39. Nirval BG, Bhosle BR, Chavan AA, Shinde JS. Response of sesame varieties to sowing dates and plant densities. J Maharashtra Agric Univ. 1995;20(3):382–4.
40. Sharma PB, Parshar RR, Ambawatia GR, Pillai PVA. Response of sesame varieties to plant populations and nitrogen levels. J Oilseeds Res. 1996;13(2):254–5.
41. Mandal SS, Das SK, Goswami SB, Pradhan BK. Yield and yield attributes of sesame as influenced by potassium nutrition and plant density. J Oilseed Res. 1990;2(4):206–9.
42. Tiwari RK, Namdeo KN. Effect of nitrogen and sulphur on growth, yield and quality of sesame (*Sesamum indicum* L.) varieties. Res Crops. 2000;1(2):163–7.
43. Basavaraj B. Response of sesame (*Sesamum indicum*) varieties to fertility and population level under irrigation during summer in paddy fields. MSc (Agri) [Thesis]. Dharwad: University of Agricultural Sciences; 1994.
44. Srinivas S, Matte DB, Thakare KK, Kene DR. Effect of different levels of nitrogen and plant density on biochemical constituents and nutrient uptake of sesame grown in Vertisol. J Soil Crops. 1991;1(1):59–65.

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