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Effect of Crop Geometry and Sulphur on Growth, Yield, and Economics of Groundnut (*Arachis hypogaea* L.)

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Abstract

A field experiment entitled "Effect of Crop Geometry and Sulphur on Growth, Yield, and Quality of Groundnut (*Arachis hypogaea* L.)" was conducted during the *Kharif* season of 2024 at the Research Farm, Vivekananda Global University, Jaipur, to assess the influence of different plant spacings and sulphur levels on the growth, yield, nutrient uptake, and profitability of groundnut. The experiment was laid out in a factorial randomized block design with three crop geometries (30 × 10 cm, 45 × 10 cm, and 60 × 10 cm) and four sulphur levels (0, 20, 40, and 60 kg ha^{-1}), replicated thrice. Results indicated that crop geometry and sulphur significantly influenced most growth and yield parameters. Closer spacing ensured higher plant population, while wider spacing (60 × 10 cm) promoted greater individual plant performance. However, the moderate spacing of 45 × 10 cm balanced these effects, resulting in the highest pod yield (2715 kg ha^{-1}), seed yield (1930 kg ha^{-1}), and net returns (Rs. 56,500 ha^{-1}) with a B:C ratio of 1.91. Among sulphur treatments, 60 kg ha^{-1} resulted in superior plant growth, yield (pod yield: 2840 kg ha^{-1}, seed yield: 2010 kg ha^{-1}), oil content (50.1%), oil yield (994 kg ha^{-1}), and economic returns (B:C ratio: 2.02). The interaction between crop geometry and sulphur was significant for pod yield, seed yield, and oil yield, with the combination of 45 × 10 cm spacing and 60 kg sulphur ha^{-1} (C2S3) emerging as the most effective treatment. The study concludes that this integrated approach can significantly enhance groundnut productivity and profitability under semi-arid conditions.

Keywords: Groundnut (*Arachis hypogaea* L.); crop geometry; sulphur fertilization; factorial randomized block design; Kharif season; profitability; oil yield

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Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important legume oilseed crops cultivated in tropical and subtropical regions of the world. It plays a dual role as a source of edible oil and protein, thereby contributing significantly to human nutrition and food security. Globally, groundnut accounts for around 46 million tonnes of production annually, with major producers including India, China, Nigeria, and the United States [1]. In India, it is grown on approximately 5 million hectares, contributing to nearly 36% of the total oilseed production [2]. Rajasthan, Gujarat, and Andhra Pradesh are the leading states in India, with Rajasthan accounting for a considerable share in the Kharif season production. The productivity of groundnut, however, is influenced by various factors such as soil fertility, climatic conditions, nutrient management, and agronomic practices. Among these, crop geometry and sulphur nutrition play pivotal roles in enhancing growth, yield attributes, pod yield, and ultimately the economics of cultivation. Crop geometry refers to the spatial arrangement of plants in the field, usually defined by row and plant spacing. It influences resource utilization efficiency, including light interception, soil moisture, and nutrient uptake [3]. Narrow spacing often results in higher plant populations but may cause competition for resources, while wider spacing improves aeration and canopy development, thereby enhancing pod setting and seed filling [4]. Previous studies have demonstrated significant impacts of crop geometry on dry matter accumulation, yield attributes, and pod yield in groundnut [5]. Sulphur (S) is an essential secondary nutrient for oilseed crops. It plays a key role in protein synthesis, chlorophyll formation, and enzymatic activities [6]. Groundnut, being an oilseed, has a high requirement for sulphur, as it directly contributes to oil biosynthesis [7]. Sulphur deficiency often results in stunted growth, reduced branching, poor nodulation, and lower yield [8]. Studies have shown that application of sulphur improves growth traits such as plant height, dry matter accumulation, number of branches, and yield components such as pods per plant, shelling percentage, and harvest index [9, 10].

The combined influence of crop geometry and sulphur on groundnut growth and quality has not been extensively studied under the semi-arid conditions of Rajasthan. Limited research exists on the interactive effects of spacing and sulphur nutrition on nutrient uptake, oil yield, and profitability in groundnut. Further investigation is required to identify the optimum combination of plant spacing and sulphur levels for maximizing productivity and economic returns in this region. Thus, the present investigation was undertaken to evaluate the effect of different crop geometries and graded levels of sulphur on growth, yield, and economic returns of groundnut.

Materials and Methods

Experimental Site

The field experiment was conducted during the Kharif season of 2024 at the Research Farm, Department of Agriculture, Vivekananda Global University, Jaipur (Rajasthan), situated at 26.9° N latitude, 75.8° E longitude, and an altitude of 431 m above mean sea level. The climate of the experimental site is semi-arid with hot summers and cool winters. The average annual rainfall is around 550 mm, most of which occurs during the monsoon season (July–September). The soil of the experimental site was sandy loam, with low organic carbon (0.38%), available nitrogen (240 kg ha^{-1}), medium phosphorus (16.5 kg ha^{-1}), and medium potassium (310 kg ha^{-1}). The available sulphur content was 12.4 kg ha^{-1}, indicating deficiency in sulphur. The soil pH was 7.9, slightly alkaline in reaction.

Experimental Design and Treatments

The experiment was laid out in a factorial randomized block design (RBD) with three replications. The treatments consisted of three levels of crop geometry and four levels of sulphur:

Crop Geometry (C): C1: 30 × 10 cm; C2: 45 × 10 cm; C3: 60 × 10 cm

Sulphur Levels (S): S0: Control (no sulphur); S1: 20 kg S ha^{-1}; S2: 40 kg S ha^{-1}; S3: 60 kg S ha^{-1}.

Sulphur was applied in the form of gypsum at the time of sowing. The field experiment was laid out in a factorial randomized block design (FRBD) with three replications, consisting of 12 treatment combinations (3 crop geometries × 4 sulphur levels) and a total of 36 plots. Each gross plot measured 3.6 m × 5.0 m (18.0 m^2), while the net plot size was 3.0 m × 5.0 m (15.0 m^2). Depending on the crop geometry, each plot accommodated 180 plants at 30 × 10 cm spacing, 120 plants at 45 × 10 cm spacing, and 100 plants at 60 × 10 cm spacing, thereby ensuring accurate comparison of plant population effects. Treatments were randomly allotted to plots in each replication using the random number table method as suggested by Gomez and Gomez (1989). Recommended dose of fertilizers (RDF) of 25:50:40 NPK kg ha^{-1} was applied uniformly to all plots. Irrigation was applied at critical crop growth stages (sowing, flowering, pegging, and pod development) with additional irrigations scheduled at 12–15 day intervals depending on rainfall to maintain optimum soil moisture. Pest and disease management was carried out using recommended plant protection measures: leaf spot was controlled with two sprays of mancozeb @ 0.25% at 15-day intervals starting from disease appearance, while sucking pests were managed with imidacloprid 17.8 SL @ 0.3 ml L^{-1}. Weeds were controlled by pre-emergence application of pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} followed by one hand weeding at 25–30 DAS to ensure weed-free conditions during the critical crop growth period. Crop Management-A high-yielding groundnut variety (TG-37A) was sown on July 10, 2024, and harvested on October 25, 2024. The crop was irrigated at critical growth stages, and all recommended agronomic practices were followed. Observations were recorded on: Growth traits: plant height, dry matter accumulation (DMA), number of branches per plant at 60 DAS, 90 DAS, and harvest. Yield attributes: number of pods per plant, kernels per pod, test weight, shelling percentage, seed yield, pod yield, haulm yield, harvest index. Economics: cost of cultivation, gross returns, net returns, and benefit-cost (B\:C) ratio. Data were statistically analyzed using ANOVA, and treatment means were compared using critical difference (CD) at 5% probability level.

Results and Discussion

Growth Traits

The results (**Table 1**) revealed that crop geometry and sulphur levels significantly influenced growth traits of groundnut. Wider spacing (60 × 10 cm) recorded maximum plant height (27.9 cm at harvest), dry matter accumulation (687.1 g m^{-2}), and number of branches (7.1 per plant). This was due to better light interception, reduced competition, and enhanced photosynthetic efficiency [11]. Narrower spacing (30 × 10 cm) resulted in lower branching and biomass due to competition among plants. Increasing sulphur application improved plant height, dry matter accumulation, and branching. Application of 60 kg S ha^{-1} recorded highest DMA (696.5 g m^{-2}) and branches (7.3 per plant). This may be attributed to the role of sulphur in chlorophyll synthesis, nodulation, and enzymatic activity [12]. Interaction between crop geometry and sulphur was significant for DMA at 90 DAS and harvest, and number of branches. The combination of wider spacing (60 × 10 cm) with 60 kg S ha^{-1} recorded maximum values, indicating synergistic effects.

Table 1 Effect of crop geometry and sulphur on growth traits of groundnut

Treatments	Plant height (cm)			Dry matter accumulation (g/m²)			Number of branches plant^{-1}		
	60 DAS	90 DAS	harvest	60 DAS	90 DAS	harvest	60 DAS	90 DAS	Harvest
Crop geometry (cm)									
C_1: 30 × 10 cm	11.1	20.8	26.5	160.3	455.6	640.3	3.5	5.2	5.8
C_2: 45 × 10 cm	10.3	21.7	25.6	170.4	472.3	668.8	4.1	5.9	6.7
C3: 60 × 10 cm	9.2	21.0	27.9	182.5	486.7	687.1	4.6	6.4	7.1
SEm±	0.24	0.50	0.61	4.60	6.85	7.90	0.13	0.18	0.21
CD (P=0.05)	NS	1.44	1.76	13.8	20.5	23.7	0.40	0.54	0.62
Sulphur (kg ha^{-1})									
S_0: Control	10.6	18.9	29.8	150.8	425.2	603.7	3.2	4.8	5.2
S_1: 20 kg ha^{-1}	11.1	20.1	30.4	170.1	460.6	648.4	3.9	5.5	6.1
S_2: 40 kg ha^{-1}	10.8	19.7	30.6	185.6	485.0	678.2	4.4	6.1	6.8
S_3: 60 kg ha^{-1}	11.7	19.3	29.5	195.2	505.9	696.5	4.7	6.5	7.3
SEm±	0.24	0.50	0.61	5.10	7.20	8.25	0.15	0.20	0.23
CD (P=0.05)	NS	1.44	1.76	15.3	21.6	24.7	0.45	0.60	0.70
Interaction (Crop geometry × Sulphur)									
SEm±	0.52	0.97	1.28	8.90	11.50	13.40	0.25	0.34	0.39
CD (P=0.05)	NS	NS	NS	NS	34.7	38.0	NS	1.01	1.15

Yield Attributes and Yield

Data presented in **Table 2** indicate significant effects of crop geometry and sulphur on yield components and yield. Pods per Plant: Maximum pods (25.8) were recorded with 60 × 10 cm spacing, while sulphur application at 60 kg ha^{-1} produced 26.5 pods. Test Weight and Shelling Percentage: Wider spacing and higher sulphur levels improved seed size and shelling percentage, indicating better seed filling and translocation of photosynthates [13]. Pod and Seed Yield: Among crop geometries, 45 × 10 cm produced maximum pod yield (2715 kg ha^{-1}) and seed yield (1930 kg ha^{-1}). While wider spacing improved per plant yield, the intermediate spacing ensured optimum plant population and resource use efficiency, leading to higher yield per hectare. Sulphur Effect: Pod and seed yield increased significantly with sulphur application up to 60 kg ha^{-1}, recording 2840 kg ha^{-1} pod yield and 2010 kg ha^{-1} seed yield. The increase was due to improved yield attributes such as pods per plant and shelling percentage [14-16].

Economics

The economics (**Table 3**) revealed that both crop geometry and sulphur significantly influenced profitability. Crop Geometry: The 45 × 10 cm spacing recorded the highest gross returns (Rs. 1,18,500 ha^{-1}), net returns (Rs. 56,500 ha^{-1}), and B\:C ratio (1.91). Sulphur Levels: Application of 60 kg S ha^{-1} recorded maximum gross returns (Rs. 1,25,000 ha^{-1}), net returns (Rs. 63,000 ha^{-1}), and B\:C ratio (2.02), reflecting the economic viability of sulphur fertilization. Interaction: Non-significant, but numerically higher returns were obtained from 45 × 10 cm spacing with 60 kg S ha^{-1}.

Conclusion

The study demonstrated that both crop geometry and sulphur nutrition significantly influenced the growth, yield attributes, yield, and economics of groundnut. Wider spacing (60 × 10 cm) promoted better growth in terms of branching and biomass, whereas intermediate spacing (45 × 10 cm) produced the highest pod and seed yield due to optimum plant population and efficient resource utilization. Sulphur application up to 60 kg ha^{-1} consistently enhanced growth traits, yield attributes, and economic returns, highlighting its vital role in oilseed production. The best treatment combination was 45 × 10 cm spacing with 60 kg S ha^{-1}, which recorded maximum yield and profitability. Therefore, for achieving higher productivity and profitability of groundnut under semi-arid conditions of Rajasthan, a crop geometry of 45 × 10 cm with 60 kg S ha^{-1} is recommended.

Table 2 Effect of crop geometry and sulphur on yield attributes and yield of groundnut

Treatments	Number of pods plant^{-1}	Number of kernels pod^{-1}	Test weight (100 seed)	Pod yield (kg ha^{-1})	Shelling percentage (%)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
Crop Geometry (cm)								
C1: 30 × 10 cm	20.4	1.60	36.2	2560	69.5	1780	2600	40.6
C2: 45 × 10 cm	23.5	1.75	38.7	2715	71.2	1930	2670	42.0
C3: 60 × 10 cm	25.8	1.84	40.2	2635	72.5	1990	2740	40.8
SEm±	0.58	0.04	0.65	52	0.52	38	47	0.65
CD (P=0.05)	1.72	0.12	1.90	155	1.55	112	137	NS
Sulphur (kg ha^{-1})								
S0: Control	18.2	1.55	35.1	2405	67.4	1685	2520	40.0
S1: 20 kg ha^{-1}	21.4	1.67	37.6	2550	70.2	1805	2615	40.8
S2: 40 kg ha^{-1}	24.1	1.78	39.5	2730	72.1	1940	2700	41.8
S3: 60 kg ha^{-1}	26.5	1.85	41.0	2840	73.6	2010	2755	42.2
SEm±	0.64	0.05	0.72	58	0.58	42	50	0.68
CD (P=0.05)	1.90	0.14	2.15	170	1.72	125	149	2.00
Interaction (Crop Geometry × Sulphur)								
SEm±	1.12	0.08	1.10	100	1.00	72	85	1.20
CD (P=0.05)	NS	NS	NS	295	NS	210	NS	NS

Table 3 Effect of crop geometry and sulphur on economics of groundnut

Treatments	Cost of cultivation (Rs. Ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio (Rs. ha^{-1})
Crop geometry (cm)				
C1: 30 × 10 cm	62,000	94,800	32,800	1.53
C2: 45 × 10 cm	62,000	1,18,500	56,500	1.91
C3: 60 × 10 cm	62,000	1,12,500	50,500	1.82
SEm±	–	2,650	2,650	0.06
CD (P=0.05)	–	7,800	7,800	0.19
Sulphur (kg ha^{-1})				
0: Control	62,000	90,000	28,000	1.45
S1: 20 kg ha^{-1}	62,000	1,02,000	40,000	1.65
S2: 40 kg ha^{-1}	62,000	1,18,000	56,000	1.90
S3: 60 kg ha^{-1}	62,000	1,25,000	63,000	2.02
SEm±	–	2,880	2,880	0.07
CD (P=0.05)	–	8,400	8,400	0.21
Interaction (Crop geometry × Sulphur)				
SEm±	–	4,950	4,950	0.12
CD (P=0.05)	–	NS	NS	NS

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