Impact of Sowing Dates, Planting Geometry and Fertility Levels on Growth and Yield of Groundnut (*Arachis hypogaea* L.) in the Foothill Conditions of Nagaland

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10.18805/ag.D-6271

ABSTRACT

Background: Groundnut yields in India have remained low due to factors like low-yielding varieties, inadequate plant populations, poor soil fertility and water management; while lower nitrogen fertilizer doses may suffice, adequate phosphorus and potassium are essential for higher yields. Improved varieties can boost yields by about 20% and gypsum enhances seedling vigour, yield and quality. Optimizing plant density, particularly by reducing row spacing, promotes better growth and increased pod formation. These factors highlight the need to study sowing dates, planting geometry and fertility levels for groundnut in Nagaland's foothill conditions, where they could significantly influence crop productivity.

Methods: A field experiment was conducted to focus on to look at the effects of planting dates, planting geometry and fertility levels on groundnut in Nagaland's special foothill settings, as these factors may have a big impact on crop productivity.

Result: The study demonstrates that optimizing sowing date, fertility levels and planting geometry significantly enhances groundnut productivity under the foothill conditions of Nagaland. Among the tested treatments, early sowing on June 20th, 125% RDF and a planting geometry of 50 cm × 10 cm resulted in the highest seed yield (1.69 t ha^{-1}), tallest plants (33.07 cm) and improved soil nutrient uptake (available nitrogen: 250 kg ha^{-1}, phosphorus: 20.37 kg ha^{-1}, potassium: 139.25 kg ha^{-1}). These findings highlight the crucial role of timing, nutrient management and spatial arrangement in maximizing crop growth, resource efficiency and yield potential. By adopting these optimized agronomic practices, farmers in the region can significantly improve groundnut production, contributing to better food security and agricultural sustainability.

Key words: Fertility levels, Groundnut, Planting geometry, Sowing dates.

INTRODUCTION

In dryland agriculture, farmers often face constraints in choosing optimal sowing times, but in irrigated systems, the timing of sowing becomes a critical non-monetary factor influencing crop yields (Sardana and Kandhol, 2007). Groundnut yields in India remain low due to various factors such as the use of low-yielding varieties, inadequate plant populations and poor soil fertility and water management. While lower doses of nitrogenous fertilizers may suffice, the adequate application of phosphorus and potassium is essential for achieving higher yields. Research indicates that adopting improved varieties can increase yields by approximately 20%. Moreover, the application of gypsum has been shown to enhance seedling vigour, seed yield and overall quality by improving soil physical characteristics (Annadurai *et al*., 2009). Recent studies also support the benefits of improved genotypes and nutrient management strategies in varied agro-ecological regions.

Groundnut (*Arachis hypogaea*), also known as peanut, is a vital crop globally, serving as the fourth most important source of edible oil and the third most important source of vegetable protein. Its nutritional composition includes 46.22% lipid, 25.20% crude protein and 21.26% carbohydrate (USDA, 2020), making it a key contributor to diets, particularly in alleviating protein-energy malnutrition. Groundnut production worldwide reaches 51 million tons annually, with India contributing 9.179 million tons from 5.31 million hectares (FAO, 2020). In Nagaland, the crop is cultivated on 930 hectares, yielding approximately 960 metric tons (Government of Nagaland, 2020). The favourable agro-ecological conditions in the Northeast region support high yields and low aflatoxin levels, presenting significant potential for expanded cultivation and

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How to cite this article: Jamir, Z., Tzudir, L., Solo, V., Dolie, S., Nongmaithem, D., Yadav, R., Kikon, N. and Dutta, M. (2025). Impact of Sowing Dates, Planting Geometry and Fertility Levels on Growth and Yield of Groundnut (*Arachis hypogaea* L.) in the Foothill Conditions of Nagaland. *Agricultural Science Digest*. **45 (Special Issue):** 73-78. doi: 10.18805/ag.D-6271.

Submitted: 24-12-2024 **Accepted:** 17-03-2025 **Online:** 10-05-2025

export. Planting geometry plays a critical role in maintaining the microclimate in cropping areas. Optimal spacing enhances light utilization, improves aeration within the crop canopy, boosts soil respiration and facilitates better weed control, all of which contribute to higher crop yields (Gautam *et al*., 2008). There is growing concern about the long-term adverse effects of excessive and indiscriminate use of inorganic fertilizers on soil fertility and crop productivity, as such practices can negatively impact the complex biogeochemical cycles (Sharma *et al*., 2014). Therefore, optimizing plant density is crucial for maximizing groundnut yields per hectare. Higher plant populations can be achieved by reducing row spacing. Proper spacing also promotes better plant growth, leading to timely reproductive phases and increased pod formation. Given these considerations, it is imperative to investigate the effects of sowing dates, planting geometry and fertility levels on groundnut under the unique foothill conditions of Nagaland, where these variables could significantly impact crop productivity.

MATERIALS AND METHODS

The present investigation was conducted at the experimental farm of the School of Agricultural Sciences, Nagaland University, Medziphema campus, Nagaland, during the period from 2019 to 2021. The experimental site, located at 25°45′09.2″N latitude and 93°51′18.6″E longitude, is situated at an altitude of 310 m above sea level. The area experiences a humid sub-tropical climate, characterized by hot, humid summers and cold winters. The monsoon season spans from early June to September, with average annual rainfall ranging from 1800 to 2500 mm with summer temperatures range from 21°C to 32°C, while winter temperatures rarely fall below 8°C. The soil at the experimental site is clayey loam with an acidic pH of 4.93. It is medium in organic carbon (1.33%), available nitrogen (250 kg ha^{-1}), available phosphorus (20.37 kg ha^{-1}) and available potassium (139.25 kg ha^{-1}).

The experiment was laid out in a split plot design with three replications, with two main factors: Sowing dates (D_1: 20th June and D_2: 10th July) and fertility levels (F_1: 75% RDF, F_2: 100% RDF and F_3: 125% RDF). Subplot treatments consisted of planting geometry: (S1) 30 cm × 10 cm, (S_2) 40 cm × 10 cm and (S3) 50 cm × 10 cm, resulting in a total of 18 treatments, as follows: $D_1F_1S_1$, $D_1F_1S_2$, $D_1F_1S_3$, $D_1F_2S_1$, $D_1F_2S_2$, $D_1F_2S_3$, $D_1F_3S_1$, $D_1F_3S_2$, $D_1F_3S_3$, $D_2F_1S_1$, $D_2F_1S_2$, $D_2F_1S_3$, $D_2F_2S_1$, $D_2F_2S_2$, $D_2F_2S_3$, $D_2F_3S_1$, $D_2F_3S_2$ and $D_2F_3S_3$.

In this experiment, groundnut variety ICGS 76 was used. Primary tillage was carried out using a tractor-drawn disc plough during the last week of May for both years, followed by final ploughing and clod breaking with a rotavator. Stubbles, debris and undecomposed plant materials were cleared from the site and the plots were laid out according to the experimental plan. Fertilizers, including nitrogen (urea), phosphorus (single super phosphate) and potassium (muriate of potash), were applied at sowing while gap filling (F_1 at 75% RDF- 15 kg N ha^{-1} + 45 kg P ha^{-1} + 30 kg K ha^{-1}, F_2 at 100% RDF- 20 kg N ha^{-1} + 60 kg P ha^{-1} + 40 kg K ha^{-1} and F_3 at 125% RDF- 25 kg N ha^{-1} + 75 kg P ha^{-1} + 50 kg K ha^{-1}) was performed 10 days after sowing to ensure a uniform plant population and two hand weedings were conducted during the vegetative and reproductive stages. The crop was harvested at physiological maturity when the lower leaves began to dry and harvesting was done using a spade and the pods were separated manually. The harvested pods and stover from each treatment were sundried and weighed separately. Data were statistically evaluated using the F-test (Gomez and Gomez, 1984) and observations from both years were combined and analyzed using standard statistical procedures.

RESULTS AND DISCUSSION

Date of sowing

The date of sowing had a significant impact on groundnut growth and yield attributes. Early sowing on June 20th (D) resulted in superior growth parameters compared to July 10th (D_2). The D_1 treatment recorded the highest plant height (32.59 cm at 90 DAS, Table 1), number of branches (10.48 per plant at 90 DAS, Table 1) and number of leaves (76.04 per plant at 90 DAS, Table 1). The pod yield and haulm yield were also highest under D_1 (19.22 pods per plant and an average kernel yield of 1.57 t ha^{-1}, with haulm yield of 2.61 t ha^{-1}, Table 2). The improved performance under early sowing is attributed to better climatic conditions during the vegetative and reproductive growth phases. Late sowing (D_2) led to lower growth and yield due to reduced vegetative growth and reproductive efficiency (Sharma *et al*., 2013).

Fertility levels

Fertility levels significantly influenced the growth and yield of groundnut. The application of 125% RDF (D_1 F_3) resulted in the tallest plants (32.59 cm at 90 DAS, Table 1), the highest number of branches (10.48 per plant, Table 1) and the highest leaf count (76.04 per plant, Table 1). Similarly, kernel yield was highest under D_1 F_3 (1.69 t ha^{-1}, Table 3), followed by 100% RDF (D_1 F_3) with a kernel yield of 1.53 t ha^{-1} (Table 3). These results align with earlier studies that emphasized the importance of enhanced nutrient supply for maximizing productivity in semi-arid and rainfed systems. The lowest yield was recorded under 75% RDF (D_2 F_1), with only 1.01 t ha^{-1} kernel yield and 1.99 t ha^{-1} haulm yield (Table 2). These results indicate that increasing fertility levels up to 125% RDF improves growth and productivity, likely due to better nutrient availability and uptake (Sharma *et al*., 2013).

Planting geometry

The effect of planting geometry was significant in all growth parameters. The widest spacing (50 cm × 10 cm, S_3) led to better plant height (31.70 cm at 90 DAS, Table 1), more branches (8.10 per plant, Table 1) and more leaves (74.28 per plant, Table 1). The highest kernel yield (1.35 t ha^{-1}, Table 2) and haulm yield (2.48 t ha^{-1}, Table 2) were recorded under S_3 (50 cm × 10 cm), which provided optimal space for plant growth. The narrowest spacing (30 cm × 10 cm, S_1)

Table 1: Effect of date of sowing, fertility levels and planting geometry on plant height, number of branches and number of leaves in groundnut.

Treatment	Plant height (cm)						Number of branches						Number of leaves					
	60 DAS			90 DAS			60 DAS			90 DAS			60 DAS			90 DAS		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Date of sowing and fertility levels																		
D_1F_1	22.70	22.26	22.48	30.27	30.80	30.54	7.18	7.23	7.21	9.77	9.84	9.81	51.18	51.92	51.55	73.88	73.80	73.84
D_1F_2	24.51	24.18	24.35	32.32	32.53	32.43	8.07	8.12	8.09	10.33	10.49	10.41	51.81	52.59	52.20	74.61	74.79	74.70
D_1F_3	24.73	24.40	24.56	32.49	32.70	32.59	8.23	8.19	8.21	10.47	10.49	10.48	52.25	54.10	53.17	75.61	75.04	75.33
D_2F_1	19.58	19.25	19.42	27.51	27.25	27.38	6.20	6.38	6.29	8.63	8.73	8.68	50.30	50.97	50.63	71.92	72.01	71.96
D_2F_2	21.28	20.92	21.10	30.08	29.48	29.78	7.13	7.23	7.18	9.37	9.60	9.48	50.79	51.63	51.21	73.40	73.19	73.30
D_2F_3	22.60	22.32	22.46	30.16	30.26	30.21	7.21	7.31	7.26	9.64	9.81	9.73	51.05	51.64	51.35	73.53	73.06	73.30
SEm±	0.67	0.58	0.44	0.57	0.40	0.35	0.28	0.24	0.18	0.20	0.18	0.13	0.20	0.26	0.16	0.31	0.23	0.19
CD at 5%	2.11	1.83	1.31	1.80	1.26	1.03	0.88	0.74	0.54	0.63	0.56	0.39	0.63	0.83	0.49	0.98	0.73	0.57
Planting geometry																		
S_1	20.34	20.40	20.37	28.96	28.69	28.83	6.96	7.08	7.02	9.21	9.29	9.25	50.84	51.74	51.29	73.37	72.61	72.99
S_2	23.33	22.36	22.84	30.82	31.04	30.93	7.01	7.00	7.00	9.80	9.96	9.88	51.30	51.88	51.59	73.87	74.02	73.95
S_3	24.03	23.91	23.97	31.63	31.78	31.70	8.05	8.15	8.10	10.09	10.24	10.17	51.55	52.81	52.18	74.24	74.32	74.28
SEm±	0.34	0.31	0.23	0.25	0.36	0.22	0.16	0.15	0.11	0.12	0.12	0.08	0.11	0.19	0.11	0.22	0.19	0.15
CD at 5%	0.99	0.89	0.65	0.73	1.04	0.62	0.47	0.45	0.32	0.34	0.36	0.24	0.33	0.57	0.32	0.64	0.56	0.41

resulted in reduced plant height, branches and leaf number due to increased competition for light, water and nutrients (Bahadur and Singh, 2005).

Interactions

a) Date of sowing × fertility levels (D × F)

- D_1 F_3 recorded the highest kernel yield (1.69 t ha^{-1}, Table 3) and haulm yield (2.79 t ha^{-1}, Table 3), while the lowest values were observed under D_2 F_1.
- Early sowing combined with higher fertility levels enhanced growth attributes due to better nutrient uptake and favorable growing conditions (Sharma *et al.*, 2013).

b) Date of sowing × planting geometry (D×S)

- D_1 S_3 (June 20th sowing with 50 cm × 10 cm spacing) showed the best results in plant height, number of branches and yield (Table 4).

Table 2: Effect of date of sowing, fertility levels and planting geometry on number of pods plant^{-1}, kernel and haulm yield in groundnut.

Treatment	Number of pods plant^{-1}			Kernel yield (t ha^{-1})			Haulm yield (t ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Date of sowing and fertility levels									
D_1F_1	18.13	17.68	17.90	1.27	1.17	1.22	2.41	2.29	2.35
D_1F_2	19.15	18.94	19.04	1.58	1.48	1.53	2.58	2.51	2.54
D_1F_3	19.41	19.04	19.22	1.65	1.49	1.57	2.69	2.54	2.61
D_2F_1	16.43	15.81	16.12	1.02	1.00	1.01	2.10	1.88	1.99
D_2F_2	17.79	17.38	17.59	1.17	1.14	1.15	2.23	2.08	2.15
D_2F_3	17.57	17.55	17.56	1.23	1.14	1.18	2.26	2.09	2.17
SEm±	0.31	0.26	0.20	0.02	0.02	0.01	0.04	0.06	0.03
CD at 5%	0.97	0.80	0.59	0.06	0.06	0.04	0.11	0.18	0.10
Planting geometry									
S_1	16.45	16.35	16.40	1.20	1.14	1.17	2.13	1.98	2.06
S_2	18.75	18.48	18.61	1.36	1.27	1.32	2.45	2.31	2.38
S_3	19.04	18.37	18.70	1.40	1.30	1.35	2.56	2.40	2.48
SEm±	0.28	0.11	0.15	0.02	0.01	0.01	0.03	0.03	0.02
CD at 5%	0.83	0.32	0.43	0.05	0.04	0.03	0.09	0.08	0.06

Table 3: Interaction effect of date of sowing, fertility levels and planting geometry on number of pods plant^{-1}, kernel and haulm yield.

Date of sowing and fertility levels × Planting geometry	Number of pods plant^{-1}			Kernel yield (t ha^{-1})			Haulm yield (t ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
$D_1F_1S_1$	16.73	16.44	16.59	1.17	1.09	1.13	2.35	2.25	2.30
$D_1F_1S_2$	18.92	18.60	18.76	1.30	1.18	1.24	2.37	2.25	2.31
$D_1F_1S_3$	18.73	18.00	18.36	1.33	1.25	1.29	2.52	2.38	2.45
$D_1F_2S_1$	15.34	17.61	16.48	1.48	1.40	1.44	2.48	2.09	2.29
$D_1F_2S_2$	19.32	19.62	19.47	1.57	1.49	1.53	2.60	2.69	2.65
$D_1F_2S_3$	22.79	19.58	21.19	1.69	1.54	1.62	2.65	2.75	2.70
$D_1F_3S_1$	18.68	17.95	18.32	1.42	1.39	1.40	2.22	2.36	2.29
$D_1F_3S_2$	19.51	19.34	19.42	1.68	1.55	1.62	2.83	2.69	2.76
$D_1F_3S_3$	20.03	19.83	19.93	1.85	1.53	1.69	3.01	2.57	2.79
$D_2F_1S_1$	14.44	13.97	14.20	0.86	0.98	0.92	1.81	1.73	1.77
$D_2F_1S_2$	17.97	16.61	17.29	1.11	1.03	1.07	2.08	1.75	1.92
$D_2F_1S_3$	16.87	16.87	16.87	1.10	1.00	1.05	2.40	2.18	2.29
D_2F2S_1	16.87	16.56	16.72	1.10	0.98	1.04	1.97	1.84	1.91
$D_2F_2S_2$	18.57	18.01	18.29	1.19	1.20	1.19	2.39	2.17	2.28
$D_2F_2S_3$	17.94	17.56	17.75	1.23	1.23	1.23	2.33	2.22	2.28
$D_2F_3S_1$	16.65	15.57	16.11	1.16	0.98	1.07	1.93	1.64	1.78
$D_2F_3S_2$	18.20	18.71	18.46	1.29	1.20	1.25	2.40	2.34	2.37
$D_2F_3S_3$	17.87	18.36	18.11	1.23	1.23	1.23	2.44	2.29	2.37
SEm±	0.69	0.27	0.37	0.04	0.03	0.02	0.07	0.07	0.05
CD at 5%	2.02	0.79	1.06	0.11	0.09	0.07	0.21	0.20	0.14

Table 4: Interaction effect of date of sowing, fertility levels and planting geometry on plant height, number of branches and number of leaves.

Date of sowing	Plant height (cm)						Number of branches						Number of leaves					
and fertility levels	60 DAS			90 DAS			60 DAS			90 DAS			60 DAS			90 DAS		
× Planting geometry	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
$D_1F_1S_1$	19.87	19.57	19.72	29.22	29.55	29.39	6.20	6.43	6.32	9.10	9.17	9.13	50.57	51.23	50.90	72.97	72.63	72.80
$D_1F_1S_2$	22.55	21.55	22.05	29.36	30.85	30.11	6.83	6.73	6.78	9.80	9.83	9.82	51.50	50.71	51.11	74.42	74.66	74.54
$D_1F_1S_3$	25.69	25.66	25.67	32.24	31.99	32.12	8.50	8.53	8.52	10.40	10.53	10.47	51.46	53.82	52.64	74.25	74.09	74.17
$D_1F_2S_1$	21.64	21.64	21.64	31.58	31.96	31.77	7.43	7.77	7.60	9.63	9.70	9.67	52.31	51.21	51.76	74.49	72.86	73.68
$D_1F_2S_2$	24.71	23.71	24.21	32.04	32.68	32.36	7.73	7.60	7.67	10.13	10.43	10.28	50.63	51.65	51.14	73.96	75.00	74.48
$D_1F_2S_3$	27.19	27.19	27.19	33.33	32.96	33.15	9.03	9.00	9.02	11.23	11.33	11.28	52.49	54.91	53.70	75.38	76.50	75.94
$D_1F_3S_1$	25.28	25.91	25.60	31.83	32.36	32.10	8.20	8.37	8.28	10.47	10.20	10.33	52.30	56.25	54.27	75.73	74.73	75.23
$D_1F_3S_2$	22.99	21.99	22.49	32.65	32.56	32.60	7.67	7.30	7.48	10.07	10.17	10.12	51.46	51.56	51.51	74.85	74.57	74.71
$D_1F_3S_3$	25.91	25.28	25.60	32.98	33.17	33.07	8.83	8.90	8.87	10.87	11.10	10.98	52.99	54.49	53.74	76.26	75.82	76.04
$D_2F_1S_1$	17.86	17.86	17.86	25.26	24.21	24.73	5.93	5.97	5.95	7.70	7.88	7.79	49.56	50.33	49.94	70.68	71.40	71.04
$D_2F_1S_2$	21.33	20.33	20.83	28.55	28.78	28.66	6.20	6.57	6.38	9.40	9.43	9.42	50.79	51.07	50.93	73.41	73.05	73.23
$D_2F_1S_3$	19.56	19.56	19.56	28.72	28.77	28.74	6.47	6.60	6.53	8.80	8.87	8.83	50.56	51.50	51.03	71.66	71.57	71.62
$D_2F_2S_1$	19.04	19.04	19.04	28.55	27.98	28.27	6.20	6.23	6.22	8.70	8.80	8.75	50.06	50.56	50.31	73.77	72.15	72.96
$D_2F_2S_2$	22.85	21.85	22.35	30.73	29.45	30.09	7.53	7.50	7.52	10.03	10.33	10.18	51.45	53.55	52.50	72.85	73.75	73.30
$D_2F_2S_3$	21.95	21.89	21.92	30.95	31.02	30.99	7.67	7.97	7.82	9.37	9.67	9.52	50.86	50.79	50.83	73.57	73.68	73.63
$D_2F_3S_1$	18.37	18.37	18.37	27.34	26.10	26.72	7.77	7.73	7.75	9.67	9.97	9.82	50.25	50.84	50.54	72.57	71.87	72.22
$D_2F_3S_2$	25.55	24.71	25.13	31.56	31.92	31.74	6.07	6.30	6.18	9.37	9.53	9.45	51.95	52.74	52.35	73.74	73.08	73.41
$D_2F_3S_3$	23.89	23.89	23.89	31.57	32.74	32.16	7.80	7.90	7.85	9.90	9.93	9.92	50.96	51.35	51.15	74.28	74.24	74.26
SEm±	0.83	0.75	0.56	0.61	0.87	0.53	0.39	0.37	0.27	0.28	0.30	0.21	0.28	0.48	0.27	0.53	0.47	0.36
CD at 5%	2.43	2.18	1.59	1.79	2.55	1.52	1.15	1.09	0.77	0.83	0.87	0.59	0.81	1.39	0.78	1.56	1.38	1.01

- D_2 S_1 (July 10th sowing with 30 cm × 10 cm spacing) had the lowest values across all parameters, indicating that late sowing with close spacing restricts growth (Bala *et al.*, 2011).

c) Fertility levels × planting geometry (F×S)

- F_3 S_3 (125% RDF with 50 cm × 10 cm spacing) recorded the highest growth and yield (Table 3).
- F_1 S_1 (75% RDF with 30 cm × 10 cm spacing) had the lowest performance due to limited nutrient availability and increased competition.

d) Date of sowing × fertility levels × planting geometry (D×F×S)

- D_1 F_3 S_3 (June 20th sowing, 125% RDF and 50 cm × 10 cm spacing) resulted in the highest plant height (33.07 cm, Table 4), branches (10.98 per plant, Table 4) and yield (1.69 t ha^{-1} kernel and 2.79 t ha^{-1} haulm, Table 3).
- D_2 F_1 S_1 (July 10th sowing, 75% RDF and 30 cm × 10 cm spacing) had the lowest values, confirming the importance of early sowing, higher fertility and wider spacing for optimal groundnut productivity (Sharma *et al.*, 2013).

The study demonstrates that the best combination for maximizing groundnut growth and yield under foothill conditions of Nagaland is June 20th sowing (D_1), 125% RDF (F_3) and 50 cm × 10 cm spacing (S_3). This combination results in the highest plant height, number of branches, number of leaves and yield components (Table 1, Table 2, Table 3). For maximum net returns and benefit-cost ratio, early sowing with 100% RDF and wider spacing is also recommended. The findings highlight the significance of optimizing sowing dates, fertility levels and planting geometry to enhance groundnut productivity and profitability (Sharma *et al.*, 2013; Bala *et al.*, 2011).

CONCLUSION

The study demonstrates that optimizing sowing date, fertility levels and planting geometry significantly enhances groundnut productivity under the foothill conditions of Nagaland. Among the tested treatments, early sowing on June 20th, 125% RDF and a planting geometry of 50 cm × 10 cm resulted in the highest seed yield (1.69 t ha^{-1}), tallest plants (33.07 cm) and improved soil nutrient uptake (available nitrogen: 250 kg ha^{-1}, phosphorus: 20.37 kg ha^{-1}, potassium: 139.25 kg ha^{-1}). These findings highlight the crucial role of timing, nutrient management and spatial arrangement in maximizing crop growth, resource efficiency and yield potential. By adopting these optimized agronomic practices, farmers in the region can significantly improve groundnut production, contributing to better food security and agricultural sustainability.

ACKNOWLEDGEMENT

Authors are thankful to Department of Agronomy and School of Agricultural Sciences (SAS), Medziphema campus, Nagaland University.

Conflict of interest

All authors declare no conflict of interest.

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