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Optimizing Nutrient Management for Enhanced Performance in Kadiri Lepakshi Groundnut

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted to determine the optimal fertilizer levels for Kadiri Lepakshi groundnut. The experiment consists of eight treatments and was laid out in randomized complete block design with three replications. The present investigation was conducted at Integrated Farming System demonstration plot, ZARS, UAS, GKVK, Bengaluru Karnataka, during the summer of 2022 and Kharif *2023*. Five plants from the sampling area were randomly selected and observations on

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growth and yield parameters were recorded at 30, 60 and 90 days after sowing (DAS) and at harvest. The results revealed that among the various nutrient levels, application of 100 % RDF combined with Phosphogypsum @ 750 kg ha^{-1} and Borax @ 10 kg ha^{-1} resulted in significantly higher values for plant height (32.95 cm), number of branches per plant (12.60) and dry matter production at harvest. This treatment also led to a substantial increase in the total number of pods per plant (59) and filled pods per plant (48) in groundnut, performing on par with the treatment that included 100% RDF, Gypsum @ 750 kg ha^{-1} and Borax @ 10 kg ha^{-1} (with 57 and 44 pods, respectively) when compared to other treatments. The similar trend was observed with respect to pod yield (2327 kg ha^{-1}), kernel yield (1580 kg ha^{-1}), and haulm yield (3594 kg ha^{-1}). So, the application of 100% RDF with Phosphogypsum @ 750 kg ha^{-1} and Borax @ 10 kg ha^{-1} significantly enhanced growth attributes (plant height, branches per plant, and dry matter production) and yield parameters (pods per plant, filled pods, pod yield, kernel yield, and haulm yield) in groundnut. This indicates that Phosphogypsum is an effective source of calcium and sulfur for boosting groundnut yield.

Keywords: Kadiri lepakshi; phosphogypsum; yield.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is also known as king of oil seeds is a member of the Papilionoideae subfamily and Leguminosae family. Groundnut gets its botanical name from the Greek words “arachis,” which means “legume” and “hypogaea” which means “below the ground”, referring to the development of pods below the soil surface. Groundnut is grown in kharif, rabi and summer seasons. However, approximately 80 per cent of the acreage and production is from kharif season.

Indian soils suffer from low productivity due to several production constraints, which include poor and imbalanced nutrition and growing crop on marginal lands. Therefore, it is essential to pay greater attention to the nutrition in order to enhance its productivity. The primary nutrients *i.e*., nitrogen, phosphorus and potassium are given priority and very little attention is paid towards the secondary nutrients and micronutrients, which are having prime importance in providing nutrients to groundnut. Calcium and sulphur requirement of groundnut is quite heavy. In neutral and alkaline soils, calcium deficiency may become serious (Das et al. 2015). Furthermore, groundnut draws a lot of nutrients from the soil, it is relatively an exhausting crop in comparison to other legume crops. According to Chandra et al. 2006, groundnut crop typically extracts 84 kg of potassium, 20 kg of phosphorus and 112 kg of nitrogen from one hectare. Gypsum is widely utilized as a source of calcium and sulphur for groundnut.

Gypsum is widely utilized as a source of calcium and sulphur for groundnut. Gypsum dissolves quickly, allowing calcium and sulphur to be added to the podding zone with ease. About 18.6 per cent of sulphur and 23 per cent of calcium are present in the gypsum. Gypsum should be applied around the base of the plant because developing pods and pegs absorb the calcium from the pod zone, which is located 5 cm below the surface of the soil. Gypsum application enhances soil structure which helps in easy penetration of pegs into the soil Kadirimangalam et al. 2004.

A solid waste byproduct of the wet phosphoric acid production process from rock phosphate is phosphogypsum. For every ton of phosphoric acid produced, approximately 5 tons of phosphogypsum is generated. It provides sizable amounts of phosphorus (0.2–1.2 %), calcium (21 %) and sulphur (13-16 %). Furthermore, phosphogypsum contains trace amounts of iron (Fe_2O_3), silica (SiO_2), aluminium (Al_2O_3), potassium (K_2O), sodium (Na_2O) and a few heavy elements. Phosphogypsum’s low solubility made it a persistent mineral that left behind nutrients for subsequent crops Rashid et al. 1989.

The Acharya N. G. Ranga Agriculture Research Institute in Kadiri, Andhra Pradesh, released the groundnut genotype Kadiri Lepakshi in 2020. This Spanish variety is a high yielding (35 q ha^{-1}), high oil content (51 %), high protein content (28 %) and produces a greater number of pods per plant. It is also resistant to drought, pests and diseases. It produces consistent yields (15-20 q ha^{-1}) even during the worst droughts. The main drawback of this genotype is improper filling of pods and its flavour is inferior for table top consumption. On the other side, the seeds of this variety do not mix with other types because of the unique colour of kernels, which distinguishes it from other varieties. The potential yield of any genotype might be realized only when it is backed up by good agronomic practices. Since different groundnut varieties have varying yield potential, it is essential to standardize nutrient supply for the specific crop variety. Therefore, in order to fully realize the potential of Kadiri Lepakshi genotype within a specific agro-climatic environment, more information about the variety with sowing technique, spacing and fertilizer requirement must be generated. Keeping this background in view, the research has been conducted to know response of Kadiri Lepakshi groundnut to different fertilizer levels.

2. MATERIALS AND METHODS

Field experiment: A field experiment was conducted during the summer season of 2022 and kharif 2023 at L-Block, GKVK, Bengaluru-65, in the Eastern Dry Zone of Karnataka (Zone-5) at an altitude of 930 meters above sea level (13˚08' N Latitude and 77˚58' E Longitude). The experimental site's soil was red sandy loam, with a pH of 6.45 (slightly acidic), electrical conductivity of 0.24 dS m^{-1}, and organic carbon content of 0.46 per cent. Soil nutrient levels were low in available nitrogen (270 kg ha^{-1}), medium in available phosphorus (51 kg ha^{-1}), and potassium (204 kg ha^{-1}).

The study involved eight treatments arranged in a randomized complete block design (RCBD) with three replications, incorporating different doses of RDF (25-50-25 kg of N, P_2O_5, and K_2O ha^{-1}), gypsum and phosphogypsum. The treatments included T_1: 75% RDF, T_2: 100% RDF, T_3: 125% RDF, T_4: 100% RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 k kg ha^{-1}, T_5: 100% RDF + Gypsum @ 750 kg ha^{-1}, T_6: 100% RDF + Phosphogypsum @ 750 kg ha^{-1}, T_7: 100% RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}, and T_8: 100% RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}. Additionally, $ZnSO_4$ @ 10 kg ha^{-1} was applied to all treatments. The experimental site was uniformly irrigated before sowing and fertilization, with subsequent irrigations every 10-15 days until the crop reached physiological maturity to maintain adequate soil moisture in the root zone.

Land preparation: The land was prepared by plowing with a disc plow, followed by cultivation, and then achieving fine tilth using a rotavator. Stubble and weeds were cleared from the experimental area prior to plot preparation. The plots were arranged according to the layout plan, and bunds were constructed around each plot.

Fertilizer application: Farmyard manure (10 tonnes ha^{-1}) was applied 15 days prior to sowing and mixed well with the soil. The fertilizer dose as per the treatments in the form of urea, single super phosphate and muriate of potash were applied. At the time of sowing 50 per cent of nitrogen, entire dose of phosphorous and potassium were applied in the furrows and mixed with the soil. Gypsum and phosphogypsum were applied as per the treatment just before flowering through furrow placement near the root zone.

Collection of experimental data: Five plants from sampling area were randomly selected and observations regarding growth and yield parameters at 30 DAS, 60 DAS, 90 DAS and at harvest were recorded. Destructive sampling was carried out from the observation area by randomly picking five plants and cutting them at ground level.

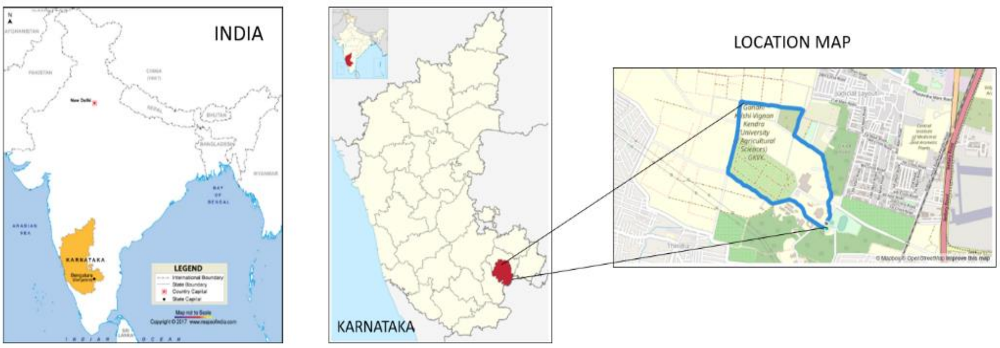

Fig. 1. Map illustrating the location of the study area for the experiment

Statistical analysis: The data recorded on various parameters were subjected to Fisher's method of analysis of variance and interpretation of the data was made as suggested by Gomez and Gomez 1984. The level of significance used in 'F' and 't' test was P = 0.05. Whenever F-test was significant for comparison amongst the treatment means an appropriate value of critical differences (CD) was worked out. If F-test was found not significant then, CD values were abbreviated as NS (Non-significant).

3. RESULTS AND DISCUSSION

3.1 Effect of Nutrient Levels on Growth Parameters

Plant height (cm): Table 1 shows pooled data on groundnut plant height across various growth stages under different nutrient levels. Plant height consistently increased with age, with the most significant growth occurring after 30 days after sowing, followed by a slower rate of increase in later stages**.**

Higher plant height at 60 DAS was noticed in the treatment which received 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (23.41 cm), which was statistically at par with the application of 100 % RDF + Gypsum @ 750 kg ha $^{-1}$ + Borax @ 10 kg ha^{-1} (22.44 cm) compared to other nutrient levels. Whereas, significantly lower plant height was observed with the treatment received 75% RDF (18.25 cm). At 90 days after sowing (DAS) and at harvest, the highest plant heights were observed with the application of 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}, recording 31.37 cm and 32.95 cm, respectively. This treatment was comparable to 100% RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (30.86 cm and 32.31 cm), 100 % RDF + Gypsum at 500 kg ha^{-1} + Borax @ 10 kg ha^{-1} (28.99 cm and 29.94 cm), and 125% RDF alone (28.60 cm and 29.60 cm).

The increase in plant height with 100% RDF and Phosphogypsum can be attributed to a balanced nutrient supply, enhanced calcium and sulfur from Phosphogypsum, which supports soil conditioning, cell division, and protein synthesis. Phosphogypsum's higher sulfur (16%) and calcium (21%) content compared to gypsum likely contributed to increased growth, while boron enhanced photosynthetic and metabolic activities, further promoting plant growth Naresha et al. 2018.

Table 1. Plant height of groundnut at different growth stages as influenced by nutrient levels

Treatments	60 DAS			90 DAS			At harvest		
	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled
T_1 : 75 % RDF	18.85	17.64	18.25	24.68	25.73	25.21	25.22	25.07	25.14
T_2 : 100 % RDF	19.97	18.70	19.33	25.83	25.90	25.87	27.78	26.46	27.12
T_3 : 125 % RDF	21.05	20.00	20.52	28.97	28.23	28.60	30.45	28.74	29.60
T_4 : 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1}	21.17	20.15	20.66	29.00	28.98	28.99	30.87	29.00	29.94
T_5 : 100 % RDF + Gypsum @ 750 kg ha^{-1}	20.00	19.70	19.85	27.25	26.33	26.79	28.07	27.10	27.58
T_6:100 % RDF + Phosphogypsum @ 750 kg ha^{-1}	20.69	19.56	20.13	28.22	27.33	27.78	28.56	27.88	28.24
T_7 : 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	22.87	22.00	22.44	30.17	31.55	30.86	32.39	32.24	32.31
T_8: 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	23.86	22.96	23.41	31.00	31.75	31.37	32.87	33.02	32.95
S. Em. ±	0.89	0.85	0.75	1.21	1.17	1.27	1.29	1.29	1.19
C. D. at 5%	2.72	2.60	2.28	3.67	3.55	3.86	3.91	3.94	3.62

Table 2. Number of branches of groundnut at different growth stages as influenced by nutrient levels

Treatments	60 DAS			90 DAS			At harvest		
	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled
T_1 : 75 % RDF	7.50	7.45	7.47	9.02	8.38	8.70	9.47	9.65	9.56
T_2 : 100 % RDF	8.26	8.40	8.33	9.59	8.67	9.13	10.42	9.71	10.07
T_3 : 125 % RDF	9.20	9.95	9.58	10.10	10.43	10.27	10.93	11.20	11.07
T_4 : 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1}	9.56	10.01	9.79	10.37	10.56	10.46	11.79	12.50	12.14
T_5 : 100 % RDF + Gypsum @ 750 kg ha^{-1}	8.78	8.47	8.46	9.14	9.02	9.08	10.60	10.30	10.45
T_6:100 % RDF + Phosphogypsum @ 750 kg ha^{-1}	9.10	9.42	9.26	10.05	9.10	9.58	11.93	11.80	11.87
T_7 : 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	10.45	11.41	10.93	11.06	10.42	10.74	12.00	11.98	11.99
T_8: 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	10.80	11.77	11.28	11.78	11.37	11.57	12.33	12.88	12.60
S. Em. ±	0.38	0.35	0.33	0.46	0.49	0.40	0.46	0.50	0.48
C. D. at 5%	1.17	1.08	1.10	1.39	1.49	1.21	1.40	1.53	1.45

Number of branches: Data on the number of branches per plant (Table 2) shows a slight increase up to 30 days after sowing, followed by a linear increase until 60 DAS. Afterward, the number of branches continued to rise until 90 DAS but at a decreasing rate.

At 60 DAS, the number of branches per plant varied significantly with nutrient levels. Significantly higher number of branches was observed with the application of 100 % RDF + Phosphogypsum @ 750 + Borax @ 10 kg ha^{-1} (11.28), which was followed by the application of 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (10.93). The lowest branch count occurred with 75 % RDF (7.47). At 90 DAS and at harvest, the highest branch counts were again recorded with 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (11.57 and 12.60, respectively), comparable to 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (10.74 and 11.99) and 100 % RDF + Gypsum @ 500 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} (10.46 and 12.14). The lowest branch counts at these stages were also with 75 % RDF (8.70 at 90 DAS, 9.56 at harvest).

The increase in branch numbers may be attributed to improved root development facilitated by sulfur, which enhanced the uptake of N, P, K, and sulfur from the soil, boosting metabolic activity (Kalaiyarasan et al. 2003, Salke et al. 2010). Phosphogypsum provided a steady supply of phosphorus, sulfur, and calcium, ensuring balanced primary and secondary nutrients that promoted optimal photosynthesis and metabolism. This effect was notably seen in the treatment with 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} and Borax @ 10 kg ha^{-1}, aligning with findings by Naresha et al. 2018.

Dry matter production (g plant^{-1}): Groundnut dry matter production varied significantly across growth stages with different nutrient levels, as shown in Fig. 2.

At 30 DAS, dry matter accumulation per plant showed no significant differences. By 60 DAS, however, significantly higher dry matter was observed with 100% RDF + Phosphogypsum @ 750 kg ha^{-1}+ Borax @ 10 kg ha^{-1} (31.98 g plant^{-1}), comparable to 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1} (30.48 g plant^{-1}). This trend continued at 90 DAS, with the highest dry matter accumulation in the 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} treatment (50.27 g plant^{-1}), statistically similar to treatments with 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}, 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1}, 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} alone and 125 % RDF. The lowest dry matter accumulation across stages was consistently recorded with 75 % RDF.

The increase in dry matter accumulation is likely due to enhanced cell multiplication, elongation, and expansion throughout growth, supported by an ample supply of essential nutrients. This nutrient availability boosted photosynthate production, ultimately improving growth attributes. Dry matter production was significantly influenced by phosphorus and gypsum levels, with the highest accumulation observed in treatments receiving 100% RDF combined with either Gypsum or Phosphogypsum @ 750 kg ha^{-1} and borax @ 10 kg ha^{-1}. Phosphogypsum's phosphorus contribution may have promoted root system expansion enhancing nutrient and water uptake and resulting in greater biomass production (Sharma et al. 1997).

3.2 Effect of Nutrient Levels on Yield Attributes and Yield

Yield attributes: Table 3 shows that total pod count per groundnut plant varied significantly with nutrient levels. The highest pod count (59) was observed with 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}, comparable to 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (57). The lowest pod count (44) was recorded with 75 % RDF**.** The highest number of filled pods per plant (48) was recorded with 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}, comparable to 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (44). This was followed by 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax 2 10 kg ha^{-1} (38) and 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} (34). The lowest filled pod counts were observed with 75 % RDF (25) and 100 % RDF alone (27). The data indicates a decrease in the number of pods per groundnut plant with the application of phosphogypsum and gypsum (Table 3). The lowest pod counts were observed with 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (11), comparable to 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (12). In contrast, significantly higher counts of unfilled pods were noted with 75 % RDF (19) and 100 % RDF (18).

The increase in pods per plant can be attributed to sulfur's role in energy storage, carbohydrate metabolism, and enzyme activation, which enhance photosynthetic activity (Banu et al. 2017). Additionally, boron supports nitrogen fixation during nodule formation and facilitates the transfer of sugars and proteins from leaves to pods, resulting in a higher pod count and increased seed index.

The increase in filled pods may be attributed to both gypsum and phosphogypsum, which provide adequate calcium for shell formation. Calcium also improves soil workability, aiding peg penetration and increasing the number of filled pods. Maintaining an optimal Ca:B ratio supports growth, flower induction, peg formation, and pollen viability, ultimately enhancing groundnut yield (Ransing et al. 2020). Additionally, boron is crucial for nodule-forming bacteria, leading to increased nitrogen fixation and higher pod counts per plant, as noted by Srinivasan and Angayarkanni 2008.

Higher pops counts are linked to the unavailability of nutrients, specifically calcium and sulfur, which are crucial for pod filling. This underscores the importance of these nutrients, alongside NPK, in pod formation. Gypsum application can enhance peanut yield in high-potential years by increasing calcium availability in the fruiting zone (Wiatrak et al. 2006).

Yield: Table 4 presents data on groundnut yield in relation to different nutrient levels. The highest pod yield and kernel yield were recorded with 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (2327 kg ha^{-1} and 1580 kg ha^{-1}), which was comparable to 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (2219 kg ha^{-1} and 1485 kg ha^{-1}) and 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1} (2034 kg ha^{-1} and 1296 kg ha^{-1}). The highest haulm yield was observed with the treatment of 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (3594 kg ha^{-1}), which was comparable to 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1} (3512 kg ha^{-1}), 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1} (3427 kg ha^{-1}), 100 % RDF +

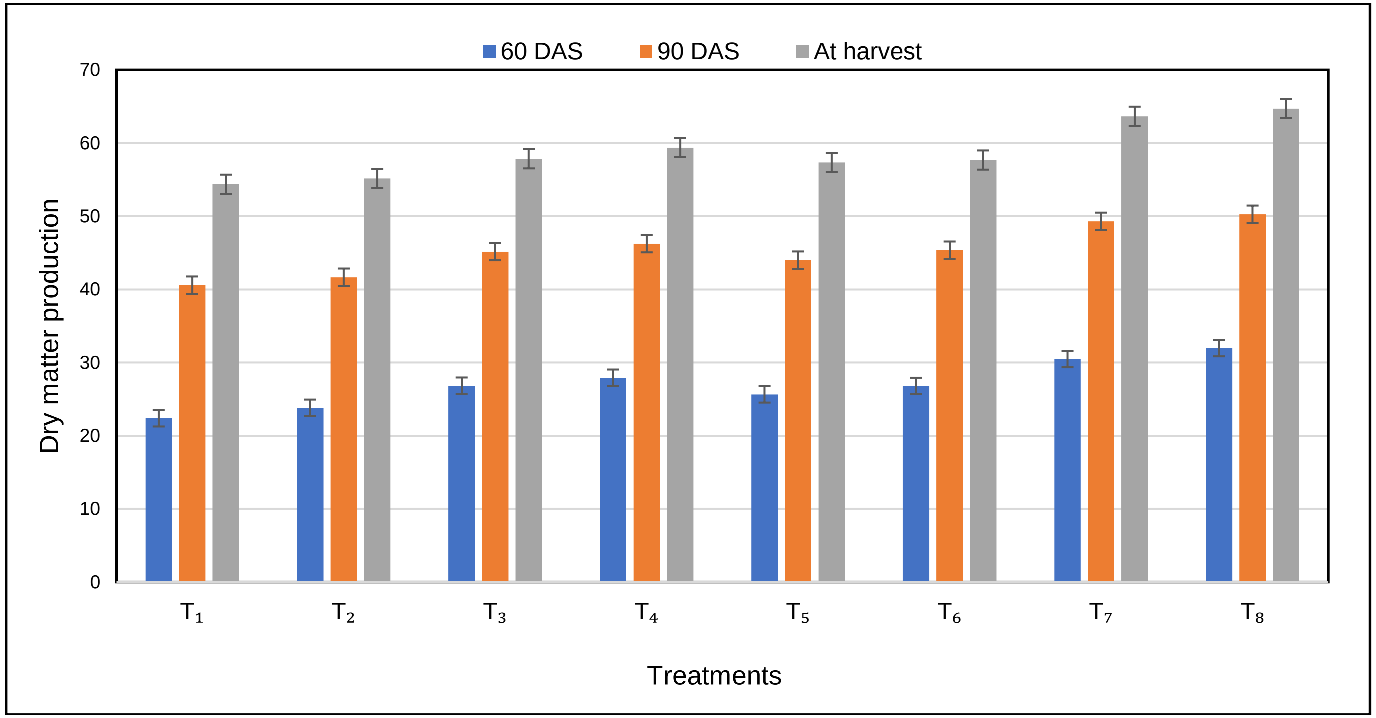

Fig. 2. Dry matter production (g plant^{-1}) of groundnut at different growth stages as influenced by nutrient levels

Table 3. Yield attributes of groundnut as influenced by nutrient levels

Treatments	Total pods plant^{-1}			Filled pods plant^{-1}			Pops plant^{-1}		
	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled
T_1 : 75 % RDF	48	40	44	29	21	25	19	19	19
T_2 : 100 % RDF	48	42	45	30	24	27	18	18	18
T_3 : 125 % RDF	49	47	48	34	31	33	15	16	16
T_4 : 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1}	53	51	52	40	36	38	14	15	14
T_5 : 100 % RDF + Gypsum @ 750 kg ha^{-1}	50	47	48	34	30	32	16	16	16
T_6:100 % RDF + Phosphogypsum @ 750 kg ha^{-1}	50	48	49	35	33	34	15	15	15
T_7 : 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	58	55	57	46	43	44	12	13	12
T_8: 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	61	58	59	50	46	48	11	11	11
S. Em. ±	2.11	2.01	1.95	1.73	1.58	1.46	0.86	0.66	0.71
C. D. at 5%	6.40	6.11	5.92	5.26	4.81	4.44	2.62	2.01	2.16

Table 4. Pod yield, kernel yield and haulm yield of groundnut as influenced by nutrient levels

Treatments	Pod yield (kg ha^{-1})			Kernel yield (kg ha^{-1})			Haulm yield (kg ha^{-1})		
	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled	Summer 2023	*Kharif* 2023	Pooled
T_1 : 75 % RDF	1602	1583	1593	929	901	915	3110	2908	3009
T_2 : 100 % RDF	1656	1566	1611	979	910	944	3077	3156	3116
T_3 : 125 % RDF	1820	1752	1786	1134	1080	1107	3159	3187	3173
T_4 : 100 % RDF + Gypsum @ 500 kg ha^{-1} + Borax @ 10 kg ha^{-1}	2060	2009	2034	1321	1272	1296	3398	3456	3427
T_5 : 100 % RDF + Gypsum @ 750 kg ha^{-1}	1796	1763	1780	1098	1093	1096	3226	3387	3306
T_6:100 % RDF + Phosphogypsum @ 750 kg ha^{-1}	1901	1819	1860	1206	1146	1176	3313	3398	3356
T_7 : 100 % RDF + Gypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	2244	2193	2219	1516	1454	1485	3556	3467	3512
T_8: 100 % RDF + Phosphogypsum @ 750 kg ha^{-1} + Borax @ 10 kg ha^{-1}	2383	2271	2327	1625	1535	1580	3639	3549	3594
S. Em. ±	88.82	90.62	92.36	58.22	58.38	53.70	105.90	105.78	108.72
C. D. at 5%	269.42	274.8	280.1	176.62	177.0	162.9	321.23	320.87	329.77

Phosphogypsum @ 750 kg ha^{-1} (3356 kg ha^{-1}) and 100 % RDF + Gypsum @ 750 kg ha^{-1} (3306 kg ha^{-1}). In contrast, the lowest haulm yield was recorded with 75 % RDF (3009 kg ha^{-1}).

The application of Phosphogypsum led to higher pod and haulm yields. The sulfur present in Phosphogypsum enhances the availability of other nutrients in the soil and their uptake by plants, creating a nutritionally favourable environment. Additionally, Phosphogypsum's relatively low solubility, compared to highly soluble sulfur sources, ensures a prolonged availability of sulfur. These findings align with the research of Singh et al. 2016, Chattopaddhya and Ghosh 2012, Rout et al. 2009. These results align with the findings of Sreelatha et al. 2004. Boron application supports chlorophyll synthesis, photosynthesis, enzyme activation, grain formation, and carbohydrate metabolism, enhancing nutrient uptake and ultimately increasing groundnut yield Naiknaware et al. 2015.

4. CONCLUSION

It was inferred that among the various nutrient levels, the application of 100% RDF + Phosphogypsum at 750 kg ha^{-1} + Borax at 10 kg ha^{-1} resulted in significantly greater growth attributes, including plant height, number of branches per plant, and dry matter production at all growth stages and it remained on par with 100% RDF + Gypsum at 750 kg ha^{-1} + Borax at 10 kg ha^{-1}. This treatment also led to improved yield attributes, such as the total number of pods per plant and filled pods per plant, ultimately resulting in higher pod yield, kernel yield, and haulm yield. This indicates that phosphogypsum is as an effective source of both calcium and sulfur to increase groundnut yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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