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IMPACT OF BIO-NANO DAP ON GROWTH AND YIELD OF GROUNDNUT AT REDUCED FERTILIZER APPLICATION RATES AND ITS COMPARISON WITH STATE RECOMMENDED DOSE OF FERTILIZERS

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2025 at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, to evaluate the integrated effects of soil-applied phosphorus and foliar Bio-Nano DAP on groundnut. The study employed a Randomized Block Design (RBD) with four replications. Six treatments combined graded levels of soil-applied phosphorus (40, 55, 70, 85, and 100% of the State Recommended Dose of Fertilizer, SRDF) with two foliar Bio-Nano DAP applications. The 100% SRDF with two foliar sprays of Bio-Nano DAP sprays achieved the significantly highest plant height (44.08 cm), number of pods per plant (20.39), pod yield (37.51 q ha^{-1}) and total chlorophyll content. It also resulted in the maximum nutrient content by plants, alongside a positive post-harvest accumulation of macro and micronutrients in the soil, indicating enhanced soil health. Crucially, reducing soil phosphorus by 15% (85% RDF) when combined with Bio-Nano DAP resulted in statistically equivalent yields. This demonstrates that Bio-Nano DAP can offset a reduction in conventional phosphorus fertilizer without compromising productivity, with the full SRDF + Bio-Nano DAP combination being optimal.

Keywords **:** Bio-Nano DAP, SRDF, groundnut, soil health, nutrients, RBD.

Introduction

Groundnut (*Arachis hypogaea* L.) is a legume crop belongs to *Leguminosae* family. It is known as king of vegetable oilseed crops and plays an important role in meeting the demand of edible oil across the world (Saravanan *et al*., 2025). Kernels of groundnut contains 47-50% oil, 26% protein and 11.5% starch (Devappa *et al*., 2025). Groundnut is cultivated in almost all tropical and subtropical countries in the world. China ranks first in groundnut production with 18.38 million tonnes followed by India 10.13 million tonnes, Nigeria 4.28 million tonnes. In India, about 48.80 lakh hectares were reported under groundnut during 2023-24 and the production was estimated about estimated at 102.89 lakh tonnes (Zankat *et al*., 2025). Rajasthan is the 2nd largest producers of groundnut after Gujarat with produces around 21.24 lakh tonnes and an area of 8.74 lakh ha with a yield of around 2364 kg/ha (Anonymous, 2024).

Among various problems that affecting the productivity of groundnut is improper nutrient management. As nitrogen is vital for the synthesis of amino acids, which serve as the fundamental components of proteins, and it often acts as a limiting factor for crop growth, development, and yield. Similarly, phosphorus plays a crucial role in biomass production, root growth stimulation, and the distribution of photosynthates between source and sink tissues. Deficiency of phosphorus in soil can severely restrict the growth and productivity of leguminous crops (Devappa *et al*., 2025). To enhance the effectiveness of soil amendments, strategies should focus on improving fertilizer–plant contact, which enhances nutrient absorption. Reducing fertilizer particle size increases the number of particles per unit weight and the specific surface area, thereby improving nutrient availability and uptake efficiency (Kumari *et al*., 2017).

Nanoparticles are smaller than 100 nm which can enhance fertilizer efficiency by improving nutrient utilization in plants, reducing environmental pollution and dissolving more readily in water that facilitates better absorption and translocation within plant tissues (Zheng *et al*., 2005; Sunil *et al*., 2025). Consequently, nano-phosphatic fertilizers hold great promise in minimizing the dependence on conventional chemical fertilizers while improving the availability of phosphorus and other vital nutrients to crops (Bakry *et al*., 2022; Balachandrakumar *et al*., 2024). Reducing fertilizer particle size will boost the efficacy of amendments which in turn increase fertilizer contact with plants and thus increase nutrient uptake (Devi *et al*., 2012). However, there remains a significant research gap in understanding the combined effects of reduced soil-applied phosphorus levels and foliar application of Bio-Nano DAP in groundnut production. It is proposed that Bio-Nano DAP could effectively replace a portion of soil-applied phosphorus without negatively affecting yield, thus improving phosphorus use efficiency. Hence, this study was undertaken to assess the combined influence of varying soil-applied phosphorus levels and foliar Bio-Nano DAP on groundnut growth, yield performance, nutrient composition and soil health.

Materials and Methods

Experimental site

The field experiment was carried out during the *Kharif* season of 2025 at Field No. 12 of the Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Rajasthan). The experimental site is located at 26°51′ N latitude, 75°47′ E longitude, and an elevation of 390 meters above mean sea level in Jaipur district, Rajasthan. The area falls within Agro-Climatic Zone IIIa, known as the Semi-Arid Eastern Plain Zone of the state. The soil of the experimental field was classified as loamy sand, slightly alkaline in reaction, low in organic carbon and available nitrogen, and medium in available phosphorus and potassium. The climate of the region is semi-arid, characterized by low atmospheric humidity and wide temperature fluctuations, with summer temperatures reaching up to 45.5°C and winter temperatures dropping to around 4°C. The average annual rainfall ranges between 500 and 700 mm, with the majority of precipitation occurring from July to September.

Collection and analysis of soil and plant samples

Soil sampling and analysis were conducted to evaluate the nutrient status and chemical properties of the experimental site. Composite soil samples were collected from each plot at a depth of 0–30 cm during both sowing and harvest stages of the groundnut crop. The samples were air-dried, gently crushed, and passed through a 2 mm sieve to obtain uniform material for laboratory examination. Soil pH and electrical conductivity (EC) were measured in a 1:2.5 soil-to-water suspension using a digital pH meter and conductivity meter, respectively, following the method described by Jackson (1973). Available nitrogen was determined by the alkaline permanganate method as proposed by Subbiah and Asija (1956). Available phosphorus was extracted with 0.5 M sodium bicarbonate solution (pH 8.5) following the procedure of Olsen *et al*. (1982), which is suitable for neutral to alkaline soils. Exchangeable potassium was estimated by extracting the soil with 1N neutral ammonium acetate (NH_4OAc) and analyzing the extract using a flame photometer, as outlined by Knudsen *et al*. (1982). Exchangeable calcium and magnesium were quantified through complexometric titration with EDTA (El Mahi *et al*., 1987) while available sulfur was estimated using the turbidimetric method based on barium sulfate precipitation (Verma *et al*., 1977). Micronutrient availability (Fe, Mn, Cu, Zn and B) was determined using the DTPA extraction method, which effectively assesses plant-available forms of these elements in soil (Lindsay and Norvell, 1978). For plant analysis, kernel and haulm samples were collected separately from each plot at harvest. The samples were oven-dried at 60°C to a constant weight and finely ground for nutrient estimation. Total nitrogen content was determined using the micro-Kjeldahl method after digestion with a mixture of H_2SO_4 and H_2O_2 (1:1) (Parkinson and Allen, 1975). Total phosphorus was analyzed by the vanadomolybdate yellow colorimetric method following wet digestion with a mixture of H_2SO_4, $HClO_4$, and HNO_3 in a 1:4:10 ratio (Jackson, 1973). Total potassium was measured using a flame photometer after digestion with the same acid mixture (Chapman and Pratt, 1962).

Experimental details

The field experiment was laid out in a randomized block design with six treatments and four replications. The treatments were **T_1**-100% SRDF (15:60:30 $N:P_2O_5:K_2O$ kg ha^{-1}+ 400 kg Gypsum ha^{-1}), **T_2**- 100% SRDF + 2 Foliar sprays of Bio-Nano DAP, **T_3**- 85%

SRDF + 2 Foliar sprays of Bio-Nano DAP, **T_4-** 70% SRDF + 2 Foliar sprays of Bio-Nano DAP, **T_5-** 55% SRDF + 2 Foliar sprays of Bio-Nano DAP and **T_6-** 40% SRDF + 2 Foliar sprays of Bio-Nano DAP. The Bio-Nano DAP formulation was received from DCM Shriram LTD (Unit: Shriram Fertilizers & Chemicals). Raj Mungfali 4 (RG-638) variety was used in present investigation. Fertilization was carried out according to the respective treatment schedules at the time of sowing. Foliar application of Bio-Nano DAP at the rate of 500 ml per acre was sprayed to treatments T_2 to T_6 at 20 and 40 days after sowing (DAS). Observations on nutrient content, growth parameters (plant population and plant height), yield and yield attributes of groundnut were recorded separately for each treatment. The crop was sown manually by hand dibbling, maintaining a spacing of 30 cm between rows and 15 cm between plants. For growth observations, five plants were randomly selected from each plot at harvest. Yield data were obtained by harvesting each plot separately as per treatment, and the results were converted to a hectare basis and expressed in quintals per hectare (q ha^{-1}). Standard agronomic practices recommended for groundnut cultivation were followed throughout the experiment. Statistical analysis of the data was performed following the method outlined by Panse and Sukhatme (1985).

Results and Discussion

Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on soil chemical properties

The application of different levels of SRDF with foliar spray of Bio-Nano DAP significantly influenced soil fertility status of groundnut after harvest (Table 1). Soil pH and electrical conductivity remained statistically non-significant across treatments, indicating no adverse effect of fertilizer combinations on soil reaction and salinity. Organic carbon content showed a significant increase over the initial value (0.26%), with the maximum OC recorded under 100% RDF + two foliar sprays of Bio-Nano DAP (0.33%), followed by 85% RDF + 2 FS of Bio-Nano DAP (0.32). Available nitrogen, phosphorus (P_2O_5) and potassium (K_2O) contents were significantly enhanced by Bio-Nano DAP application, with the highest values observed in T_2 (150.53, 86.16, and 188.93 kg ha^{-1}, respectively). Secondary nutrients (Ca, Mg and S) also increased significantly under Bio-Nano DAP treatments compared to 100% RDF alone and the initial soil status. Micronutrients such as Zn, Fe, Mn, Cu and B exhibited a marked improvement, particularly under T_2, indicating better nutrient availability and enrichment of soil. The observed increase in available nitrogen in the soil could be attributed to the immediate supply and gradual release of nitrogen from the applied fertilizers, which aligns with the findings of Miller *et al*. (1987) and Bharadwaj and Omanwar (1994). Enhanced activity of nitrogen-fixing microorganisms may also have contributed to the significant improvement in soil nitrogen availability under NPK and Bio-Nano DAP treatments. The post-harvest soil phosphorus content was notably influenced by the treatments, likely due to the application of phosphorus fertilizers in varied forms and formulations. Similar observations were reported by Deenik *et al*. (2006), who found that phosphorus fertilization elevated soil P levels compared to the control. Increasing the levels of NPK fertilizers in the soil correspondingly enhanced the availability of these nutrients, resulting in higher concentrations of soil-available N, P, and K. In the case of potassium, the combined effect of different treatment doses led to an increase in soil potassium content, possibly due to the cumulative contribution of applied fertilizers. Prakash *et al*. (2023) also that 100% RDF + foliar spray of Nano-DAP @ 4 ml L^{-1} at 30 and 45 DAS resulted in significantly higher postharvest nutrient availability after soybean, including 215 kg ha^{-1} N, 33.77 kg ha^{-1} P_2O_5, 351 kg ha^{-1} K_2O, and 17.28 kg ha^{-1} SO_4^{2-}. Rameshaiah *et al*. (2015) concluded that nano fertilizers can improve nutrient-use efficiency (NUE) by up to three times compared with chemical fertilizers, while also enhancing stress tolerance and reducing input costs. Similar positive results were also observed by Ernane (2021).

Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on growth and yield of groundnut

Data presented in the table 2 showed that plant population was not significantly influenced by different treatments, indicating uniform crop establishment across treatments. Plant height varied significantly among treatments, with the maximum plant height (44.08 cm) recorded under 100% SRDF + 2 FS Bio-Nano DAP, which was significantly superior to most other treatments. Reduced fertilizer levels resulted in a gradual decline in plant height, with the minimum height observed under 40% SRDF + 2 FS Bio-Nano DAP (30.40 cm). The significantly increase in plant height under treatments involving optimal soil application of conventional phosphorus combined with foliar application of Bio-Nano DAP can be attributed to the enhanced nutrient availability and efficient uptake facilitated by the nano-formulation. The high surface area and permeability of Bio-Nano DAP particles likely improved foliar absorption and translocation of nutrients, thereby stimulating physiological and biochemical processes associated with plant growth. Nitrogen, supplied through Bio-Nano DAP, plays a crucial role in promoting meristematic activity and cell division, as well as in the synthesis of amino acids such as tryptophan, a precursor for auxin biosynthesis. Auxins are known to regulate cell elongation and expansion, which collectively contribute to increased plant height and overall vegetative growth. Conversely, the reduced plant height observed in treatment T_6 (40% SRDF + 2 FS Bio-Nano DAP) may be attributed to insufficient nutrient availability, particularly phosphorus and nitrogen, which are essential for sustained vegetative development. Limited nutrient supply could have restricted metabolic activity and cell proliferation, resulting in stunted growth. These findings are consistent with the results reported by Abd Alqader *et al*. (2020), Aziz and Zrar (2021) and Kumar *et al*. (2022), who also observed enhanced plant growth parameters with balanced nutrient management and nano-fertilizer applications.

The results presented in the table 2 revealed that the highest number of pods plant^{-1} (20.39) was obtained under the treatment 100% SRDF + 2 FS Bio-Nano DAP, followed by 85% SRDF + 2 FS Bio-Nano DAP (18.47), while the lowest number of pods per plant (11.65) was recorded under 40% SRDF + 2 FS Bio-Nano DAP. Similarly, the highest pod, haulm and biological yields of groundnut were observed with 100% SRDP through DAP as basal + 2 FS Bio-Nano DAP (T_2), followed by statistically comparable results in T_3 and T_1. The improvement in yield attributes and overall productivity under these treatments can be attributed to the synergistic effect of conventional and nano-fertilizers, which ensured balanced and continuous nutrient availability throughout the crop growth period, particularly during critical developmental stages. Enhanced nutrient uptake promoted vigorous vegetative growth and efficient photosynthetic activity, leading to greater accumulation and translocation of photosynthates to the reproductive organs, thereby improving pod and haulm yields. These findings are in agreement with the observations of Bhargavi and Sundari (2023). Furthermore, the highest oil content was recorded in T_2 (100% SRDP through DAP as basal + 2 FS Bio-Nano DAP), followed by T_3 (85% SRDF + 2 FS Bio-Nano DAP) and T_1 (100% SRDF), while the lowest oil content (39.90%) was observed in T_6 (Table 2). The increase in oil content with higher phosphorus levels may be attributed to enhanced glucoside formation (allyl isothiocyanate) and the role of phosphorus as a structural component of phospholipids essential for lipid synthesis (Singh and Singh, 1988). Additionally, phosphorus facilitates fatty acid synthesis and esterification by accelerating biochemical reactions in the glyoxylate cycle, thereby contributing to higher oil accumulation in groundnut kernels (Kumari *et al*., 2017).

Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on total chlorophyll content

The total chlorophyll content of groundnut leaves was significantly influenced by foliar application of Bio-Nano DAP at both observation stages (Table 3). Treatment T_2 (100% RDF + two foliar sprays of Bio-Nano DAP) recorded the highest chlorophyll content at after first spray (1.051) and after second spray (3.083), which was significantly superior to all other treatments. A progressive decrease in chlorophyll content was observed with reduction in RDF levels, even with Bio-Nano DAP application. The lowest chlorophyll content was recorded under T_6 (40% RDF + Bio-Nano DAP). The enhanced chlorophyll content under Bio-Nano DAP application may be attributed to improved nitrogen and phosphorus availability, leading to enhanced photosynthetic activity and crop vigour (Chamuah *et al*., 2023).

Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on plant nutrient contents

The nutrient content of groundnut kernels and haulm was significantly influenced by different levels of RDF in combination with foliar application of Bio-Nano DAP (Table 4). Among the treatments, 100% RDF with two foliar sprays of Bio-Nano DAP (T_2) recorded the highest nitrogen content in kernels (3.651%) and haulm (1.425%), which was significantly superior to 100% RDF alone and treatments receiving reduced RDF levels. A similar trend was observed for phosphorus content, where T_2 resulted in maximum P concentration in kernels (0.499%) and haulm (0.273%), followed closely by 85% RDF + Bio-Nano DAP (T_3). Potassium content in both kernels and haulm also showed significant improvement due to Bio-Nano DAP application, with the highest values recorded under T_2 (0.611% in kernels and 1.660% in haulm). Progressive reduction in RDF levels from 85% to 40% along with Bio-Nano DAP led to a corresponding decline in N, P, and K contents, though these treatments still performed comparably or better than 100% RDF alone. the use of nano-based foliar sprays aligns with environmentally responsible agricultural practices, curbing nitrogen's impact on the environment. Finally, the flexibility to fine-tune nutrient application with different levels of nano nitrogen ensures optimized nutrient management, while mitigating nitrogen stress, thereby enhancing the nitrogen content in the harvested crop (Azamal and

Khawaja, 2014). The results are also aligned with the findings of Rohitha (2024).

Conclusion

The synergistic application of full soil phosphorus (100% SRDF) with foliar Bio-Nano DAP sprays optimized groundnut yield, nutrient content and soil fertility. Importantly, a 15% reduction in soil phosphorus (85% SRDF) combined with Bio-Nano DAP performed comparably, demonstrating that foliar Bio-Nano DAP can effectively offset reduced soil P applications. This strategy offers a sustainable approach to maintain productivity while enhancing nutrient-use efficiency and soil health.

Table 1 : Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on soil chemical properties

Sample No.	pH	EC (dS/m)	OC (%)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Ca (ppm)	Mg (ppm)	S (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	B (ppm)
Before Sowing	6.90	0.15	0.26	125.44	71.29	175.32	6.01	4.80	0.06	1.69	1.78	3.59	0.36	0.11
T_1 100% RDF	6.87	0.10	0.31	143.62	81.94	184.28	10.01	8.34	0.10	1.93	4.23	6.01	0.40	0.19
T_2 100% RDF + 2 FS Bio-Nano DAP	6.85	0.09	0.33	150.53	86.16	188.93	11.98	9.60	0.11	2.02	5.04	7.32	0.45	0.23
T_3 85% RDF + 2 FS Bio-Nano DAP	6.86	0.10	0.32	144.82	83.63	185.62	10.12	8.40	0.11	1.98	4.68	6.09	0.42	0.22
T_4 70% RDF + 2 FS Bio-Nano DAP	6.87	0.11	0.28	139.62	80.16	181.29	8.55	7.21	0.08	1.87	4.12	5.34	0.39	0.18
T_5 55% RDF + 2 FS Bio-Nano DAP	6.88	0.13	0.28	138.71	80.05	180.56	8.27	7.00	0.08	1.83	3.78	5.30	0.38	0.16
T_6 40% RDF + 2 FS Bio-Nano DAP	6.89	0.14	0.26	138.42	79.98	180.11	8.05	6.98	0.07	1.77	3.66	5.26	0.38	0.14
SE(m)±	0.07	0.03	0.008	1.53	0.67	1.50	0.11	0.08	0.001	0.02	0.04	0.05	0.004	0.002
CD @ 5%	NS	NS	0.003	4.57	1.99	4.50	0.32	0.25	0.002	0.06	0.11	0.14	0.012	0.005
CV	2.08	1.44	1.81	2.18	1.65	1.65	2.39	2.21	1.78	2.08	1.94	1.62	1.98	1.77

Table 2 : Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on growth and yield of groundnut

Treatments	Plant Population (m^{-2})	Plant Height (cm)	Pods per plant	Pod Yield (q/ha)	Haulm Yield (q/ha)	Biomass (q/ha)	Shelling %	100 seed weight	Oil content (%)
T_1 100% RDF	18.53	40.03	17.50	32.09	47.95	80.04	77.71	76.21	46.41
T_2 100% RDF + 2 FS Bio-Nano DAP	18.75	44.08	20.39	37.51	55.99	93.49	79.78	84.22	49.42
T_3 85% RDF + 2 FS Bio-Nano DAP	18.86	40.43	18.47	33.42	49.43	82.84	78.23	78.24	46.87
T_4 70% RDF + 2 FS Bio-Nano DAP	18.50	36.26	15.58	28.32	42.06	70.39	77.45	70.80	43.10
T_5 55% RDF + 2 FS Bio-Nano DAP	18.64	34.17	13.63	24.38	36.20	60.58	77.41	67.65	41.98
T_6 40% RDF + 2 FS Bio-Nano DAP	18.44	30.40	11.65	20.71	29.81	50.53	76.90	62.24	39.90
SE(m)±	0.68	1.20	0.63	1.17	1.92	2.98	2.30	1.88	0.76
CD @ 5%	NS	3.64	1.91	3.55	5.84	9.05	NS	5.71	2.31
CV	7.35	6.37	7.73	7.95	8.82	8.16	5.91	5.13	3.40

Table 3 : Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on total chlorophyll content

Treatment	Total Chlorophyll content	
	After 1^{st} Spray	After 2^{nd} Spray
T_1 100% RDF	0.511	1.719
T_2 100% RDF + 2 FS Bio-Nano DAP	1.051	3.083
T_3 85% RDF + 2 FS Bio-Nano DAP	0.576	2.036
T_4 70% RDF + 2 FS Bio-Nano DAP	0.328	1.612
T_5 55% RDF + 2 FS Bio-Nano DAP	0.110	1.432
T_6 40% RDF + 2 FS Bio-Nano DAP	0.024	1.377
SE(m)±	0.004	0.018
CD @ 5%	0.013	0.056
CV	1.920	1.968

Table 4 : Effect of different levels of SRDF and foliar spray of Bio-Nano DAP on plant nutrient contents

Treatment	N content (%)		P content (%)		K content (%)	
	Kernels	Haulm	Kernels	Haulm	Kernels	Haulm
T_1 100% RDF	3.608	1.375	0.489	0.259	0.595	1.621
T_2 100% RDF + 2 FS Bio-Nano DAP	3.651	1.425	0.499	0.273	0.611	1.660
T_3 85% RDF + 2 FS Bio-Nano DAP	3.624	1.382	0.492	0.261	0.599	1.624
T_4 70% RDF + 2 FS Bio-Nano DAP	3.587	1.356	0.483	0.255	0.592	1.604
T_5 55% RDF + 2 FS Bio-Nano DAP	3.556	1.328	0.480	0.249	0.586	1.583
T_6 40% RDF + 2 FS Bio-Nano DAP	3.510	1.324	0.475	0.248	0.582	1.581
SE(m)±	0.014	0.011	0.003	0.002	0.005	0.014
CD @ 5%	0.044	0.035	0.009	0.006	0.009	0.045
CV	0.805	1.663	1.173	1.534	1.126	1.908

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