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Effect of nano fertilizers on the yield and economics of groundnut (*Arachis hypogaea* L.)

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Abstract

The present investigation entitled "Effect of Nano Fertilizers on the Productivity of Groundnut (*Arachis hypogaea* L.)" was conducted at AICRP on Summer Groundnut, MPKV, Rahuri during Summer 2025.The experiment consists of eleven treatments *viz*, T_1 : Absolute Control, T_2 : RDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1}), T_3 : GRDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1} + FYM 10 t ha^{-1}), T_4 : GRDF + Zinc Sulphate @ 2 g lit^{-1} foliar spray at 25 and 45 DAS, T_5 : GRDF + Nanoscale Zinc Oxide @ 2 g 15^{-1} lit foliar spray at 25 and 45 DAS, T_6 : GRDF + Nanoscale Zinc Oxide @ 2 g 10^{-1} lit foliar spray at 25 and 45 DAS, T_7 : GRDF + Nanoscale Calcium Oxide @ 2 g 15^{-1} lit foliar spray at 25 and 45 DAS, T_8 : GRDF + Nanoscale Calcium Oxide @ 2 g 10^{-1} lit foliar spray at 25 and 45 DAS, T_9 : GRDF + Nano Sulphur @ 2.5ml lit^{-1} foliar spray at 30 and 45 DAS, T_{10} : GRDF + Nano Sulphur @ 5 ml lit^{-1} foliar spray at 30 and 45 DAS, T_{11} : GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose, 50% at pegging stage.The experiment was laid out in randomized block design (RBD) with 3 replications. The soil texture of the experimental site was found to be sandy clay loam. Soil was low in available nitrogen (198.56 kg ha^{-1}), medium in available phosphorus (17.36 kg ha^{-1}), high in potassium (327.56 kg ha^{-1}), moderately high in available sulphur (15.78 mg kg^{-1}), low in available zinc (0.43 mg kg^{-1}) and high in available calcium (26.56 cmol kg^{-1}). The soil was slightly alkaline in reaction (pH 8.19) with normal in electrical conductivity of 0.33 dSm^{-1}.The results revealed that T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, recorded significantly superior performance with respect to yield and economic studies. This treatment registered the highest pod yield (36.58 q ha^{-1}), kernel yield (25.66 q ha^{-1}), haulm yield (48.23 q ha^{-1}), biological yield (84.81 q ha^{-1}), gross monetary returns (Rs. 2,26,714 ha^{-1}), net monetary returns (Rs.1,51,121 ha^{-1}) and B:C ratio (3.02). However, T_{11} was found to be statistically at par with T_{10} i.e., GRDF + Nano sulphur foliar spray @ 5 ml l^{-1} applied at 30 and 45 DAS and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} applied at 30 and 45 DAS for most of the yield and economic studies.

Key words : Groundnut, Gypsum, GRDF ,Foliar application, Yield, Economic studies.

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop belonging to the family Fabaceae (Leguminosae) and genus Arachis. The name *Arachis hypogaea* is derived from Greek, where *Arachis* denotes "legume" and *hypogaea* means "below ground," referring to its unique pod development beneath the soil surface. The crop possesses a chromosome number of 2n = 40. Groundnut is valued for its high nutritional composition, containing approximately 23-26% protein and 45–50% oil, which has earned it the titles "King of Vegetable Oilseed Crops" and "Poor Man's Nut" (Kumar *et al*., 2013). It plays a crucial role in the edible oil economy of India and is believed to have originated in South America. Globally, groundnut is a major oilseed crop contributing significantly to edible oil supplies and serving as an affordable protein source, particularly in developing countries. India is the second largest producer of groundnut after China. The major producing countries include China, India, Nigeria, Sudan, and the USA, contributing 36.01%, 13.79%, 9.12%, 5.80%, and 5.11% of global production, respectively (Anonymous, 2023). Micronutrient deficiencies, particularly of zinc and calcium, are widespread in Indian soils and human populations. Zinc deficiency affects nearly 40% of Indian soils and has significant implications for crop productivity and human health, leading to impaired immunity and growth disorders (Shukla *et al.*, 2016). Similarly, calcium deficiency in groundnut adversely affects pod development, resulting in unfilled pods and poor seed quality. In recent years, nanotechnology has emerged as a promising approach in agriculture to enhance nutrient use efficiency and crop productivity. Nanotechnology involves the manipulation of materials at the nanoscale (1-100 nm), where particles exhibit unique physicochemical properties such as increased surface area and reactivity (European Commission, 2011). In agricultural systems, nano-fertilizers offer advantages including improved nutrient availability, reduced losses, and targeted delivery. Zinc nanoparticles (ZnO NPs) have gained considerable attention due to their potential to improve seed germination, plant growth, and yield. Conventional zinc fertilizers such as zinc sulfate ($ZnSO_4$) and EDTA-chelated zinc often suffer from low efficiency due to leaching and poor retention. Moreover, zinc sulfate may cause phytotoxic effects such as leaf scorching under high-temperature conditions due to its high salt index (Kisan *et al.*, 2015). In contrast, nano-zinc formulations provide a more efficient and controlled nutrient supply (Wigginton *et al.*, 2007). Calcium is another essential nutrient for groundnut, particularly during the pod-filling stage, as developing pods absorb calcium directly from the soil. Deficiency leads to the formation of "pops" (empty pods) and reduced germination potential (Meena *et al.*, 2007). Sulphur plays a vital role in plant metabolism, including protein synthesis, chlorophyll formation, and oil biosynthesis. It is also essential for the formation of sulphur-containing amino acids such as methionine and cysteine and enhances nodulation and nitrogen fixation in legumes (Hawkesford & De Kok, 2006). Nano-sulphur formulations have shown potential to improve sulphur use efficiency by enabling slow and sustained nutrient release in the rhizosphere, thereby minimizing nutrient losses (Chen *et al.*, 2011). Furthermore, nano-fertilizers can interact effectively with soil particles, reducing nutrient fixation and improving nutrient availability. Nano-coating technologies enable controlled nutrient release, ensuring synchronization with crop demand and contributing to sustainable agricultural practices (Subramanian & Tarafdar, 2011). The present investigation entitled "Effect of Nano Fertilizers on the Productivity of Groundnut (*Arachis hypogaea* L.)" was conducted to study the effect on productivity, quality and economics of groundnut cultivation.

Materials and Methods

The field experiment was conducted during summer season of 2025 at AICRP on summer groundnut, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India). The soil texture of the experimental site was found to be sandy clay loam. Soil was low in available nitrogen (198.56 kg ha^{-1}), medium in available phosphorus (17.36 kg ha^{-1}), high in potassium (327.56 kg ha-1), moderately high in available sulphur (15.78 mg kg^{-1}), low in available zinc (0.43 mg kg^{-1}) and high in available calcium (26.56 cmol kg^{-1}). The soil was slightly alkaline in reaction (pH 8.19) with normal in electrical conductivity of 0.33 dSm^{-1}. Agro-climatically this area falls under scarcity zone (drought prone area) of Maharashtra state. There were eleven treatments laid out in randomized block design (RBD) with three replications. Each experimental plot was with gross plot size of 5.00 m x 4.50 m and net plot size of 4.60 m x 3.30 m. The experiment consists of eleven treatments *viz*, T_1 : Absolute Control, T_2 : RDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1}), T_3 : GRDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1} + FYM 10 t ha^{-1}), T_4 : GRDF + Zinc Sulphate @2 g lit^{-1} foliar spray at 25 and 45

DAS, T_5 : GRDF + Nanoscale Zinc Oxide @2 g 15^{-1} lit foliar spray at 25 and 45 DAS, T6: GRDF + Nanoscale Zinc Oxide @2 g 10^{-1} lit foliar spray at 25 and 45 DAS, T_7 : GRDF + Nanoscale Calcium Oxide @2 g 15^{-1} lit foliar spray at 25 and 45 DAS, T_8 : GRDF + Nanoscale Calcium Oxide @2 g 10^{-1} lit foliar spray at 25 and 45 DAS, T_9 : GRDF + Nano Sulphur @2.5 ml lit^{-1} foliar spray at 30 and 45 DAS, T_{10} : GRDF + Nano Sulphur @ 5 ml lit^{-1} foliar spray at 30 and 45 DAS, T_{11} : GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose, 50% at pegging stage. The variety of groundnut known as Phule unnati with seed rate of 100 kg ha^{-1} was used. Sowing was done by dibbling method with spacing 30 cm x 10 cm on January 10, 2025.

Results and Discussion

Yield parameters

Dry pod yield (q ha^{-1}) : Dry pod yield was significantly influenced by different treatments. The highest pod yield (36.58 q ha^{-1}) was recorded under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, which was significantly superior to all other treatments. This was followed by T_{10}, i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1}, which recorded 35.86 q ha^{-1} and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1}, which recorded 35.56 q ha^{-1}, both treatments were statistically at par with T_{11}. Pod yield in groundnut is the cumulative effect of efficient vegetative growth, reproductive development, pod formation and pod filling. The significantly higher pod yield recorded under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, may be attributed to the continuous and balanced supply of calcium and sulphur through split application of gypsum. Calcium plays a vital role in peg penetration, pod development and kernel formation, as developing pods absorb calcium directly from the soil. Sulphur enhances photosynthetic efficiency, protein synthesis and oil biosynthesis, leading to better assimilate production and translocation towards pods. These findings are in conformity with Krishna *et al*. (1997).

Kernel yield (q ha^{-1}) : Kernel yield (25.66 q ha^{-1}) was recorded under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, which was significantly superior to all other treatments. The treatments T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} recorded 25.08 and 24.89 q ha^{-1}, respectively and were found to be statistically at par with T_{11}. Kernel yield is directly dependent on effective pod filling and kernel development, which are highly sensitive to calcium and sulphur availability. The superior kernel yield under T_{11} can be attributed to improved calcium nutrition during pegging and pod development, ensuring better kernel growth and reduced kernel abortion. These results are in consistent with the findings of Adhikari *et al*. (2003).

Haulm yield (q ha-1) : Haulm yield (48.23 q ha^{-1}) was recorded under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, followed by T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} which recorded 47.26 q ha^{-1} and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} which recorded 47.21 q ha^{-1}, which were statistically found at par with T_{11}. Haulm yield reflects overall vegetative biomass production. The increased haulm yield under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, may be attributed to improved nutrient availability, particularly calcium and sulphur, which promote cell division, leaf expansion and stem growth. These results are in findings of Subhendu Mandal *et al*. (2005).

Biological yield (q ha^{-1}) : Biological yield (84.81 q ha^{-1}) was recorded under T_{11}, i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, followed by T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} which recorded 83.11 q ha^{-1} and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} which recorded 82.84 q ha^{-1}, which were statistically found at par with T_{11}. The lowest biological yield (52.95 q ha^{-1}) was recorded under T_1. Higher biological yield under gypsum and nano sulphur treatments indicates improved total dry matter production. Balanced nutrient supply enhanced photosynthesis, nutrient uptake and biomass accumulation. The split application of gypsum ensured sustained nutrient availability, while nano sulphur improved nutrient use efficiency, resulting in higher total biomass production.The conclusions described above are consistent with the findings of Rao and Shaktawat (2002).

Harvest Index (%) : Harvest index varied from 41.75 per cent under the absolute control (T_1) to 43.88 per cent under T_6 i.e., GRDF + Nanoscale Zinc Oxide @ 2 g 10 lit^{-1} as foliar spray at 25 and 45 DAS. Treatments T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1}, T_9 i.e., GRDF + Nano sulphur foliar spray @ 2.5 ml l^{-1} and T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal and 50% at pegging stage recorded harvest index values of 43.28, 43.08 and 42.97 per cent, respectivelyStatistical analysis revealed that differences among treatments with respect to harvest index were non-significant, indicating that although treatments influenced pod, kernel and haulm yields, the proportionate distribution of total biomass between economic yield (pods) and total biological yield remained relatively stable across treatments. This indicates that nutrient management primarily enhanced total biomass production rather than altering assimilate distribution. Samul *et al*. (2007)

Gross monetary returns : Gross monetary returns were significantly influenced by different treatments. Gross monetary returns

Table 1. Pod yield, kernal yield, haulm yield, biological yield and harvest index as influenced by different treatments at harvest of groundnut

Treatments	Pod yield (q ha^{-1})	Kernal yield (q ha^{-1})	Haulm yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1 - Absolute Control	22.25	13.80	30.70	52.95	41.75
T_2 - RDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1})	29.44	21.57	41.45	73.06	42.88
T_3 - GRDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1} + FYM 10 t ha^{-1})	32.11	21.98	42.31	74.42	42.76
T_4 - GRDF + Zinc Sulphate @ 2 g lit^{-1} foliar spray at 25 and 45 DAS	32.62	22.33	42.29	74.91	43.38
T_5 - GRDF + Nanoscale Zinc Oxide @ 2 g 15^{-1} lit foliar spray at 25 and 45 DAS	33.03	22.71	43.36	76.39	42.32
T_6 - GRDF + Nanoscale Zinc Oxide @ 2 g 10^{-1} lit foliar spray at 25 and 45 DAS	33.39	22.99	43.46	76.85	43.88
T_7 - GRDF + Nanoscale Calcium Oxide @ 2 g 15^{-1} lit foliar spray at 25 and 45 DAS	33.81	23.31	43.86	77.67	42.76
T_8 - GRDF + Nanoscale Calcium Oxide @ 2 g 10^{-1} lit foliar spray at 25 and 45 DAS	34.29	23.70	44.29	78.58	43.58
T_9 - GRDF + Nano Sulphur @ 2.5 ml lit^{-1} foliar spray at 30 and 45 DAS	35.56	24.89	47.21	82.84	43.08
T_{10} - GRDF + Nano Sulphur @ 5 ml lit^{-1} foliar spray at 30 and 45 DAS	35.86	25.08	47.26	83.11	43.28
T_{11} - GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal Dose, 50% at pegging stage)	36.58	25.66	48.23	84.81	42.97
S.E.(m)±	0.40	0.27	0.36	0.67	0.43
C.D. at 5%	1.18	0.79	1.05	1.99	NS
General Mean	32.63	22.55	43.13	75.08	42.97

across treatments were Rs. 2,02,253 ha^{-1}. The highest gross monetary returns (Rs. 2,26,714 ha^{-1}) were recorded under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, which was significantly superior to all other treatments. This was closely followed by T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} applied at 30 and 45 DAS) with Rs. 2,22,229 ha^{-1} and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} applied at 30 and 45 DAS) with Rs. 2,20,422 ha^{-1}, which were statistically at par with T_{11}. Gross monetary returns are directly dependent on pod yield and market value of the produce. The superior gross returns recorded under T_{11} can be attributed to higher pod yield resulting from improved yield attributes such as increased number of pods, filled pods and pod weight. Calcium supplied through gypsum plays a crucial role in peg penetration, pod development and kernel filling, while sulphur enhances metabolic activity and oil synthesis, ultimately increasing economic yield. These results are in agreement with those of Adhikari *et al*. (2003).

Cost of cultivation : Cost of cultivation varied across treatments depending on the type and quantity of nutrient inputs used. The highest cost of cultivation (Rs. 75,593 ha^{-1}) was incurred under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage. This was followed by T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} (Rs. 74,382 ha^{-1}) and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} (Rs. 73,406 ha^{-1}). The higher cost of cultivation under T_{11} was mainly due to the additional expense incurred on gypsum procurement, transportation and split application. Similarly, nano nutrient treatments such as T_{10} and T_9 involved higher input costs owing to the use of specialized nano formulations and multiple foliar sprays. However, despite the relatively higher cost, these treatments proved economically advantageous due to their substantial contribution to yield enhancement and monetary returns. These findings are similar to the results of Adhikari *et al*. (2003).

Table 2. Gross monetary returns, cost of cultivation, net monetary returns and B: C ratio as influenced by different treatments

Treatments	Gross monetary returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net monetary returns (Rs. ha^{-1})	B:C ratio
T_1 - Absolute Control	138105	54130	83975	2.55
T_2 - RDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1})	182858	60157	122701	3.01
T_3 - GRDF (25:50:00 N: P_2O_5 : K_2O kg ha^{-1} + FYM 10 t ha^{-1})	199027	71738	127289	2.77
T_4 - GRDF + Zinc Sulphate @ 2 g lit^{-1} foliar spray at 25 and 45 DAS	202084	72581	129502	2.78
T_5 - GRDF + Nanoscale Zinc Oxide @ 2 g 15^{-1} lit foliar spray at 25 and 45 DAS	204704	72663	132041	2.82
T_6 - GRDF + Nanoscale Zinc Oxide @ 2 g 10^{-1} lit foliar spray at 25 and 45 DAS	206840	72773	134067	2.84
T_7 - GRDF + Nanoscale Calcium Oxide @ 2 g 15^{-1} lit foliar spray at 25 and 45 DAS	209419	72636	136783	2.88
T_8 - GRDF + Nanoscale Calcium Oxide @ 2 g 10^{-1} lit foliar spray at 25 and 45 DAS	212383	72728	139656	2.91
T_9 - GRDF + Nano Sulphur @ 2.5 ml lit^{-1} foliar spray at 30 and 45 DAS	220422	73406	147015	2.98
T_{10} - GRDF + Nano Sulphur @ 5 ml lit^{-1} foliar spray at 30 and 45 DAS	222229	74382	147847	2.99
T_{11} - GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal Dose, 50% at pegging stage)	226714	75593	151121	3.02
S.E.(m)±	2385	-	2368	-
C.D. at 5%	7034	-	6986	-
General Mean	202253	-	132000	-

Net monetary returns : Net monetary returns across treatments were Rs. 1,32,000 ha^{-1}. The maximum net monetary returns (Rs. 1,51,121 ha^{-1}) were obtained under T_{11} i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage, which was significantly superior to all other treatments. This was followed by T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} (Rs. 1,47,847 ha^{-1}) and T_9 i.e., GRDF + Nano Sulphur foliar spray @ 2.5 ml l^{-1} (Rs. 1,47,015 ha^{-1}), which were statistically at par with T_{11}. Higher net monetary returns under T_{11} were primarily due to significantly higher pod yield and gross returns, which more than compensated for the increased cost of cultivation. These results are in concurrence with Adhikari *et al*. (2003).

B:C ratio : B:C ratio 3.02 was recorded under T11 i.e., GRDF + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage was found highest , followed closely by T_2 i.e., RDF 3.01 and T_{10} i.e., GRDF + Nano Sulphur foliar spray @ 5 ml l^{-1} 2.99. The lowest B:C ratio (2.55) was recorded under the absolute control (T_1). The B:C ratio is an important indicator of economic efficiency and sustainability of a production system. The highest B:C ratio under T_{11} indicates that the returns obtained from gypsum application were proportionately much higher than the cost incurred. The split application of gypsum ensured efficient nutrient utilization, resulting in higher profitability.

Interestingly, RDF alone (T_2) also recorded a high B:C ratio due to relatively lower cultivation cost and moderate yield improvement, emphasizing that balanced fertilization improves economic returns.The lower B:C ratio under the absolute control may be attributed to poor yield levels despite lower input costs, indicating that inadequate nutrient management is economically inefficient. These results are in agreement with those of Adhikari *et al*. (2003)

Conclusion

Based on the present field experiment it can be concluded that the treatment consist of General Recommended Dose of Fertilizer (25:50:00 N: P_2O_5 : K2O kg ha^{-1} + FYM 10 t ha^{-1}) + Gypsum @ 500 kg ha^{-1} 50% at basal dose and 50% at pegging stage or General Recommended Dose of Fertilizer (25:50:00 N: P_2O_5 : K_2O kg ha^{-1} + FYM 10 t ha^{-1}) + Nano Sulphur foliar spray @ 5 ml l^{-1} applied at 30 and 45 DAS or General Recommended Dose of Fertilizer (25:50:00 N: P_2O_5 : K_2O kg ha^{-1} + FYM : 10 t ha^{-1}) + Nano Sulphur foliar spray @ 2.5 ml l^{-1} applied at 30 and 45 DAS is found beneficial for increase in yield and economics.

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