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Optimising nano-nitrogen and conventional sulphur doses for enhanced growth and yield in sunflower (*Helianthus annuus*)

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ABSTRACT

The field experiment was conducted during rainy (*kharif*) season of 2024 and winter (*rabi*) season of 2025 at Annamalai University, Annamalai Nagar, Chidambaram, Tamil Nadu to study the effect of nano formulation of nitrogen and conventional sulphur on growth and yield of sunflower (*Helianthus annuus* L.) cultivated in heavy textured soil. The sunflower hybrid VEDA (KSFH-666) variety was selected for the study. The experiment consists of 11 treatments comprised of four levels of nitrogen (30, 45, 60 and 90 kg/ha) through urea and nano urea and sulphur (45 kg/ha) through gypsum. Regarding the various treatments imposed in the experiments, T_{11} (45 kg nitrogen through urea + 45 kg nitrogen through nano urea + 45 kg S/ha through gypsum) registered maximum values for growth and yield attributes, seed yield (2,722 and 2,613 kg/ha) and stalk yield (4,828 and 4,634 kg/ha) of sunflower in both crop seasons. The lowest values for growth attributes, yield attributes and yield (seed and stalk) were observed under control treatment (T_1) in both crop seasons. Experimental findings obtained from current investigation found that combined application of nano and conventional nitrogen and sulphur had a profound impact towards growth and yield attributes and yield of sunflower over control in both crop seasons.

Keywords: Nano nitrogen, Sulphur, Sunflower, Yield

Sunflower (*Helianthus annuus* L.) is an edible, short duration and photo insensitive oilseed crop in India which produces good quality oil (40–45%) and protein (16%). It is cultivated over an area of 0.36 mha in India and with a production of 0.36 mt and exhibiting 996 kg/ha of productivity. In Tamil Nadu, it is cultivated over an area of 0.10 lakhs ha with a production of 0.10 lakh tonnes and with a productivity of 1050 kg/ha (Department of Agriculture & Farmers Welfare 2024). India's per capita consumption of oil is notably low on account of low production. The reason attributed for low yield especially in sunflower might be owing to poor seed filling, insufficient soil moisture and nutrients particularly in winter and summer, variable precipitation, lack of balanced fertilisation, untimely weed management, lack of improved technologies, lack of machinery availability and labour, market fluctuations and biotic stress such as pest, disease, weed and birds, etc. To meet the increasing national demand for edible oils, it is essential to expand the area under oilseed cultivation and adopt improved production techniques. Nutrient management is one of the ways to increase production. Among the nutrients, nitrogen and sulphur play key roles in boosting oilseed productivity and meeting per capita oil requirements in India. Nitrogen is crucial for sunflower growth, contributing significantly to vegetative growth, seed yield, and oil and protein content. It enhances photosynthetic efficiency and the movement of assimilates within the plant, ultimately improving productivity. Sulphur, now recognised as the fourth essential macronutrient following nitrogen, phosphorus, and potassium, also significantly contributes to oil synthesis and the overall performance of crops. Combined application of sulphur with the recommended NPK regime improves both seed and oil yields. According to Kumar *et al.* (2020), conventional fertilisers provide nutrients in chemical forms that are difficult for plant uptake. Addressing nutrient inefficiencies within the agricultural sector necessitates the innovation of sophisticated smart materials with the ability to release nutrients in precisely controlled and targeted activity within plant systems. Such materials not only aid in correcting nutrient deficiencies but also help in maintaining the nature of the soil structure. Nano-fertilisers, due to their distinctive physicochemical characteristics, enhance plant performance by enabling ultra-efficient nutrient uptake, augmenting biomass production, promoting elevated rates of photosynthesis, and increasing leaf surface area. The controlled release properties of nano-fertilisers also helps

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to prevent environmental pollution and nutrient runoff. These nanoscale materials can penetrate plant tissues more efficiently through stomata and nanopores, leading to higher nutrient use efficiency. Nano urea (Liquid), which comprises 4% (40,000 ppm) nitrogen in its nanoscale formulation, acts as a vital macronutrient necessary for healthy plant development and growth. The nano urea foliar spray during critical growth phases has been demonstrated to sufficiently meet the nitrogen requirements of crops, resulting in superior yields and enhanced quality in comparison to traditional urea. In this part of study area, limited work has been done in sunflower to understand the effect of nano fertilisation of nitrogen and sulphur especially in heavy textured soil. By considering these facts, the current study was conducted to improve the productivity of sunflower.

MATERIALS AND METHODS

The field experiments were carried out during rainy (*kharif*) season of 2024 and winter (*rabi*) season of 2025 at Annamalai University, Annamalai Nagar, Chidambaram (11º24'N, 79º44'E; at an elevation of +5.79 m amsl), Tamil Nadu. The experimental field is characterised as clay loam textured soil exhibiting a *p*H of 7.6 and EC of 0.45 ds/m. The fertility status of field soil indicates organic carbon concentration at 0.42%, available N at low levels of 215.2 kg/ha, available P_2O_5 at medium levels of 21.8 kg/ha, available K_2O at high levels of 307.5 kg/ha and available S at low level of 9.1 kg/ha. The experiment was laid out in a randomised block design (RBD) involving 11 treatments, viz. T_1, Control; T_2, 60 kg N through urea; T_3, 30 kg N through nano urea; T_4, 30 kg N through urea + 30 kg N through nano urea; T_5, 90 kg N through urea; T_6, 45 kg N through urea + 45 kg N through nano urea; T_7, 60 kg N through urea + 45 kg S/ha through gypsum; T_8, 30 kg N through nano urea + 45 kg S/ha through gypsum; T_9, 30 kg N through urea + 30 kg N through nano urea + 45 kg S/ha through gypsum; T_{10}, 90 kg N through urea + 45 kg S/ha through gypsum; T_{11}, 45 kg N through urea + 45 kg N through nano urea + 45 kg S/ha through gypsum, which were replicated thrice. The sunflower hybrid VEDA (KSFH-666) was selected for the study. Seed rate of 4 kg/ha was utilised for sowing sunflower, following the spacing of 60 cm × 30 cm. Gap filling was done on 8 days after sowing (DAS). Thinning was followed on 10 DAS leaving a single vigorous plant/hill. The experimental crop was weeded twice by hand hoeing on 15 and 35 DAS. The prescribed treatment schedule was followed for fertilising the sunflower crop. The recommended dose of fertiliser (RDF) consisting of 60 kg N, 90 kg P, 60 kg K/ha was administered via urea, diammonium phosphate and MOP. Sulphur @45 kg/ha supplied basally in the form of gypsum, in accordance with treatment specifications before sowing. The nano urea was applied through foliar spray as referred in the treatment details at 30 and 50 DAS. Hand pollination was done on 58 DAS by rubbing the flower heads by using a soft muslin cloth. Five representative plants within the net plot were randomly selected and tagged, and systemic observations were carefully made on growth and yield attributes and yield of sunflower. Plant samples collected for the assessment of dry matter production (DMP) during 30, 60 DAS and at the harvest stage were subjected to drying at 80ºC ± 5ºC in a hot air oven for a duration of 8 h. The findings of DMP

Table 1 Effect of nano fertilisation of nitrogen and conventional sulphur on growth attributes of sunflower

Treatments	Plant height at harvest (cm)		LAI at flowering stage		DMP (at harvest) (kg/ha)		Number of leaves/plant at flowering stage		Days to 50% flowering		Stem girth at flowering stage (cm)	
	Kharif 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025
T_1	137.25	132.03	2.49	2.41	3017	2926	21.84	21.18	52.00	53.00	7.02	6.80
T_2	147.49	142.59	2.89	2.77	3732	3582	22.92	22.00	51.00	52.00	7.74	7.43
T_3	142.36	137.08	2.70	2.61	3347	3246	22.37	21.69	51.33	52.35	7.38	7.15
T_4	157.88	153.14	3.24	3.14	4391	4259	23.97	23.25	50.67	51.57	8.49	8.23
T_5	152.56	147.98	3.06	2.96	4070	3947	23.43	22.72	51.00	52.00	8.10	7.85
T_6	163.11	158.84	3.43	3.36	4845	4748	24.48	23.99	50.67	51.67	8.86	8.68
T_7	173.98	167.76	3.80	3.68	5828	5653	25.53	24.76	50.00	51.00	9.58	9.29
T_8	168.22	162.49	3.61	3.46	5394	5178	25.02	24.01	50.33	51.33	9.22	8.85
T_9	184.24	178.71	4.25	4.12	6905	6697	26.17	25.38	49.67	50.67	10.30	10.09
T_{10}	179.16	173.57	4.00	3.92	6361	6233	26.07	25.54	50.00	51.00	9.94	9.74
T_{11}	189.47	183.89	4.48	4.30	7511	7210	26.77	25.89	49.00	50.00	10.70	10.47
SEd	2.42	2.42	0.08	0.07	126.90	122.48	0.24	0.24	0.16	0.16	0.17	0.16
CD (*p*= 0.05)	5.08	5.05	0.16	0.15	266.57	255.73	0.51	0.50	0.33	0.34	0.35	0.34

DMP, Dry matter production; LAI, Leaf area index. Treatment details are given under Materials and Methods.

were articulated as kg/ha. The seed yield obtained from the net plot was quantified and documented in kg/ha. Sunflower stalks from each of the treatment plots were harvested, and following adequate exposure to sunlight for drying, the respective stalk yield was measured and recorded in kg/ha. The experimental data was statistically analysed as suggested by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Growth attributes: The nano fertilisation of nitrogen and sulphur application had a profound impact on growth parameters across all developmental stages of sunflower. Among the different experimental treatments evaluated, the combination of 45 kg N through urea + 45 kg N through nano urea + 45 kg S/ha through gypsum (T_{11}) registered higher values for plant height (189.47 and 183.89 cm), LAI (4.48 and 4.30), DMP (7511 and 7210 kg/ha), number of leaves/plant (26.77 and 25.89), days to 50% flowering (49 and 50) and stem girth/plant (10.70 and 10.47 cm) than other treatments in both crop seasons (Table 1). This treatment was closely followed by treatment T_9 that used 30 kg N through urea + 30 kg N through nano urea + 45 kg S/ha through gypsum. Lower readings for growth attributes were registered in control treatment (T_1) across both crop seasons. The increased growth parameters in T_{11} might be owing to the balanced and adequate supply of nutrients led to enhanced vegetative growth and photosynthetic activity of the crop. Nano nitrogen is effective in improving nutrient release, uptake and utilisation. Suthar *et al.* (2023) stated that the nano nitrogen foliar application has been reported to enable better absorption of nitrogen, resulting in improved utilisation efficiency (>80 %), which enhance nitrogen content in plants and thereby promotes vigorous growth. The more absorption of nitrogen by plants led to better plant health. These outcomes are congruent with the observations described by Ravikumar *et al.* (2020) and Bhakher *et al.* (2023). Addition of sulphur via gypsum improved solubility of different nutrients, thus enabling better nutrient uptake necessary for cellular increase, elongation and expansion during the entire development stage of the crop. The use of sulphur also encourages amino acid formation, leading to increased protein content and thus enhancing the nitrogen ratio in the soil. Sulphur is an integral constituent of succinyl co-A, thus utilised during the synthesis of chlorophyll in leaves along with it triggers cellular processes through the encouragement of photosynthesis, which enhances leaf area. The synergistic action of these two nutrients provides a sufficient amount of nitrogen and sulphur, leading to increased photosynthates production and mobilisation to plant's growing parts, thus enhancing growth parameters. These outcomes are similar to observations drawn by Singh *et al.* (2024) and Roy *et al.* (2024) who reported that the combination of nano

Table 2 Effect of nano fertilisation of nitrogen and conventional sulphur on yield attributes and yield of sunflower

Treatments	Head diameter (cm)		Total No. of seeds/ head		No. of filled seeds/ head		Percentage of filled seeds/head (%)		100-seed weight (g)		Seed index (g)		Seed yield (kg/ha)		Stalk yield (kg/ha)	
	Kharif 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025	*Kharif* 2024	*Rabi* 2025
T_1	22.67	21.98	557.92	541.18	353.61	343.00	63.38	61.47	4.90	4.70	40.76	39.53	1267	1228	2599	2521
T_2	24.93	23.93	705.10	676.89	527.13	506.04	74.76	71.76	4.94	4.74	43.05	41.32	1614	1549	3025	2904
T_3	23.93	23.21	665.08	645.12	452.92	439.33	68.10	66.05	4.92	4.72	42.25	40.98	1516	1470	2809	2724
T_4	26.07	25.28	784.80	761.25	611.05	592.71	77.86	75.52	4.97	4.77	46.17	44.78	1807	1752	3464	3360
T_5	25.67	24.89	717.01	695.50	548.08	531.63	76.44	74.14	4.96	4.76	45.58	44.21	1648	1598	3243	3145
T_6	26.67	26.13	811.51	795.28	644.91	632.01	79.47	77.88	5.00	4.96	46.51	45.57	1880	1815	3675	3601
T_7	27.57	26.74	937.60	909.47	786.55	762.95	83.89	81.37	5.02	5.01	49.18	47.70	2181	2115	4097	3974
T_8	27.17	26.08	849.62	815.63	697.96	670.04	82.15	78.86	5.01	5.00	47.72	45.81	1972	1893	3879	3723
T_9	29.37	28.48	1052.60	1021.02	925.66	897.89	87.94	85.30	5.06	5.05	51.11	49.57	2468	2393	4569	4431
T_{10}	27.93	27.37	1016.22	995.89	870.70	853.28	85.68	83.96	5.05	5.02	50.76	48.74	2378	2330	4300	4214
T_{11}	30.17	28.96	1154.28	1108.11	1041.97	1000.29	90.27	87.60	5.08	5.06	51.64	50.68	2722	2613	4828	4634
SEd	0.15	0.15	16.87	15.25	14.81	14.65	0.65	0.64	0.12	0.11	0.15	0.14	42.56	29.79	90.58	87.41
CD (p=0.05)	0.32	0.31	35.44	31.84	31.12	30.59	1.36	1.33	NS	NS	0.31	0.30	89.40	62.20	190.28	182.51

*NS, Non significant. Treatment details are given under Materials and Methods.

urea along with sulphur @45 kg/ha increase all the growth parameters of sunflower.

Yield attributes and yield: In both crop seasons, the nano fertilisation of nitrogen and sulphur proved to have a greater impact on yield attributing characters and yield of sunflower. Regarding the different treatments implemented, the treatment combination of 45 kg N through urea + 45 kg N through nano urea + 45 kg S/ha through gypsum (T_{11}) registered maximum values for yield attributing characters such as head diameter (30.17 and 28.96 cm), total number of seeds/head (1154.28 and 1108.11), number of filled seeds/head (1041.97 and 1000.29), seed filling percentage (90.27 and 87.60%), test weight (5.08 and 5.06 g) and seed index (51.64 and 50.68 g), yield, viz. seed yield (2722 and 2613 kg/ha) and stalk yield (4828 and 4634 kg/ha) in both crop seasons. This treatment was closely succeeded by the treatment of 30 kg N through urea + 30 kg N through nano urea + 45 kg S/ha through gypsum (T_9) (Table 2). The control treatment (T_1) registered lower values for yield parameters and yield of sunflower in both crop seasons. The augmented yield characteristics and general productivity in T_{11} could be attributed to the improved vegetative growth led to the increment in the reproductive part of the crop owing to the improved translocation of photosynthates. A balanced application of nano nitrogen and sulphur boosted nutrient uptake in sunflower, which may have triggered more enzymes for carbohydrate and protein metabolism that caused a rise in the photosynthetic activity that subsequently manifested in reproductive development. Increased availability of nutrients and its transfer to sink might be the cause for the increase in total seed count per head and head diameter. These findings are aligned with recent studies carried out by Devi *et al.* (2024) and Vyankatrao *et al.* (2024).

Correlation study: The result of correlation coefficient indicated that seed yield was positively correlated with plant height (r = 0.989).

Drawing upon the above said findings, it may be concluded that combined application of 45 kg Nitrogen through urea + 45 kg Nitrogen through nano urea + 45 kg Sulphur/ha through gypsum (T_{11}) could be agronomically sound and economically feasible technology for improving the productivity and profitability of sunflower growers in the Cauvery delta region.

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