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Effect of Different Levels of Nitrogen and Sulphur on Productivity and Quality of Sunflower (*Helianthus annuus* L.) in Central Plain Zone of Uttar Pradesh, India

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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

Nitrogen (N) and sulphur (S) are essential macronutrients that play pivotal roles in regulating crop growth, yield formation, and oil synthesis in sunflower (*Helianthus annuus* L.). A field experiment was conducted during the Zaid season of 2025 at the Crop Research Farm, School of Advanced Agricultural Sciences and Technology (SAAST), Chhatrapati Shahu Ji Maharaj University, Kanpur, Uttar Pradesh, India, to evaluate the effects of graded N and S levels on the productivity and quality of sunflower under the Central Plain Zone of Uttar Pradesh. The experiment comprised ten treatment combinations, including an untreated control (T_0) and nine combinations of N and S, with three replications, and was laid out in a randomised block design (RBD) using sunflower cultivar DRSH-1. Among the treatment combinations, the application of N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1} (T_9) resulted in the highest plant height (167.81 cm), number of leaves $plant^{-1}$ (29.3), dry matter accumulation (43.86 g m^{-2}), head diameter (20.64 cm), seed yield (2108 kg ha^{-1}), stover yield (4365 kg ha^{-1}), biological yield (6473 kg ha^{-1}), and oil yield (853.33 kg ha^{-1}). In contrast, the maximum oil content (40.76%) was recorded with N @ 90 kg ha^{-1} + S @ 50 kg ha^{-1} (T_8). Overall, the

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application of N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1} demonstrated superior performance in enhancing sunflower growth, yield attributes, seed and biomass productivity, and oil yield under the agro-climatic conditions of the Central Plain Zone of Uttar Pradesh. The findings suggest that balanced N and S nutrition can substantially improve sunflower productivity and oil production in the region.

Keywords: *Nitrogen; sulphur; sunflower; yield; yield attributes; productivity; nutrient management; oil quality; amino acid; linoleic acid.*

1. Introduction

Sunflower (*Helianthus annuus* L.*)* is an important oilseed crop belonging to the Asteraceae family. Sunflower was domesticated in North America and can be grown worldwide because it produces high-quality edible oil that is rich in polyunsaturated fatty acids, such as linoleic acid, and low in saturated fats (Pereyra-Irujo & Aguirrezábal, 2007). Besides oil, sunflower seeds are a valuable source of protein, vitamins, and minerals, making the crop economically and nutritionally important (Chauhan, 2021). Cultivated sunflower is diploid (2n=34) and contributes approximately 14% of global oilseed production (Rai *et al*., 2016). Globally, Russia, Ukraine, and Argentina are the leading sunflower-producing countries.

In India, sunflower is mainly cultivated in Karnataka, Tamil Nadu, and Telangana. However, national production has declined over recent decades due to reduced cultivation area and suboptimal crop management practices (Department of Agriculture & Farmers Welfare, 2023). In regions such as the Central Plain Zone of Uttar Pradesh, sunflower has considerable production potential because of its adaptability to diverse agro-climatic conditions, short duration, and relatively low input requirements. Nevertheless, nutrient deficiencies and imbalanced fertiliser application continue to limit productivity (Lakshmi Deepika, Singh, & R*eddy, 2022; Lakshmi Deepika, Singh, & Singh,* 2022).

Among the essential nutrients, nitrogen (N) and sulphur (S) play vital roles in sunflower growth, seed yield, and oil quality. Nitrogen is a key constituent of chlorophyll, amino acids, proteins, nucleic acids, and enzymes, thereby promoting vegetative growth, photosynthesis, and biomass production. Nitrogen deficiency leads to poor plant growth, chlorosis, delayed flowering, and reduced seed yield (Sarkar & Mallick, 2009; Usha Rani *et al.*, 2009). The significance of sulphur in plants ranks fourth after nitrogen, phosphorus, and potassium, as it plays an important role in the formation of sulphur-containing proteins, amino acids, chlorophyll, and oils. The greater sulphur requirement of oilseed crops than cereal crops is associated with oil formation. Sulphur helps improve nutrient uptake, fulfil crop requirements, support oil formation, and increase crop yield. Besides this, there is a close relationship between nitrogen and sulphur. In recent years, deficiencies of nitrogen and sulphur have become increasingly evident in agricultural soils. Nutrient deficiencies adversely affect plant growth, yield, and seed-oil quality. Various studies have shown that adequate supplies of these two nutrients improve growth and yield traits (Ramamoorthy et al., 2023; Rasool et al., 2013; Sheoran et al., 2018; Singh *et al*., 2000). Therefore, nitrogen and sulphur fertilisation must be optimised to improve sunflower performance, nutrient-use efficiency, and oil content.

Recent studies further indicate that sunflower performance can respond to nitrogen rate, timing, and fertiliser formulation, with implications for yield, seed quality, and nutrient-use efficiency (Chen et al., 2025; Haque, 2026; Shams et al., 2025). Targeted sulphur nutrition has also been reported to enhance sunflower growth and yield formation, supporting the importance of adequate sulphur supply in nutrient management (Pallavi et al., 2026). Fertiliser-dose effects on sunflower yield under differing tillage conditions and fertiliser regimes further indicate that nutrient responses can vary with the production environment (More et al., 2024; Rahman et al., 2022).

Research gap: However, the evidence summarised in this manuscript does not establish the response of sunflower to graded combinations of nitrogen and sulphur under the Central Plain Zone of Uttar Pradesh, particularly through the simultaneous evaluation of growth, yield, and oil-related traits. This context-specific gap supports the evaluation of combined N and S levels under the local agro-climatic conditions of the study.

1.1 Objective

Taking all these considerations into account, the current experiment was designed to study the effects of varying amounts of N and S fertilisers on the growth and production of sunflower (*Helianthus annuus* L.).

2. Materials and Methods

2.1 Experimental Site

A field experiment was carried out during the 2025 Zaid season at the Crop Research Farm, Department of Agronomy, School of Advanced Agriculture Science and Technology (SAAST), Chhatrapati Shahu Ji Maharaj University, Kanpur, Uttar Pradesh, India. The experimental site is located in the Central Plain Zone of Uttar Pradesh at 26.49° N latitude and 80.26° E longitude. The region has a semi-arid tropical climate, with warm and dry weather during the Zaid season. In April, the maximum and minimum temperatures varied from 36.0-37.8°C and 20.0-22.3°C, respectively, with relative humidity of 19-20% and 11-12 hours of sunshine each day. The soil was somewhat alkaline (pH 7.9), with an electrical conductivity of 0.68 dS m^{-1} and an organic carbon content of

0.37%. The soil had low available nitrogen (228 kg ha^{-1}) and phosphorus (14.25 kg ha^{-1}), medium available potassium (264 kg ha^{-1}), and good available sulphur (36.79 kg ha^{-1}).

2.2 Description of the Experimental Sites

The experiment named "Effect of Different Levels of Nitrogen and Sulphur on Productivity and Quality of Sunflower (*Helianthus annuus* L.) in the Central Plain Zone of Uttar Pradesh" was carried out with the sunflower hybrid DRSH-1 as the test crop. The experiment was set up using a randomised block design (RBD), with ten treatments and three replications. Nitrogen, phosphorus, and potassium were given via urea (NH_2CONH_2), diammonium phosphate (DAP), and muriate of potash (KCl), respectively, while sulphur was applied based on the treatments. The treatment combinations were as follows: T_0: Control, T_1: N_{70} + S_{20} kg ha^{-1}, T_2: N_{90} + S_{20} kg ha^{-1}, T_3: N_{120} + S_{20} kg ha^{-1}, T_4: N_{70} + S_{40} kg ha^{-1}, T_5: N_{90} + S_{40} kg ha^{-1}, T_6: N_{120} + S_{40} kg ha^{-1}, T_7: N_{70} + S_{50} kg ha^{-1}, T_8: N_{90} + S_{50} kg ha^{-1}, T_9: N_{120} + S_{50} kg ha^{-1} where N and S represent nitrogen and sulphur application rates (kg ha^{-1}), respectively. The collected data were statistically analysed using **analysis of variance (ANOVA)** for a randomised block design **(RBD),** as described by Gomez and Gomez (1984).

3. Result and Discussion

3.1 Plant Height (cm)

At harvest, T9 (N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1}) recorded the numerically highest plant height (167.81 cm), followed closely by T6 (N @ 120 kg ha^{-1} + S @ 40 kg ha^{-1}; 167.56 cm) and T3 (N @ 120 kg ha^{-1} + S @ 20 kg ha^{-1}; 166.29 cm), whereas the control (T0) recorded 159.26 cm (Table 1; Fig. 1). Relative to the control, T9 increased plant height by 8.55 cm (5.37%). However, this difference was smaller than the critical difference at P = 0.05 (CD = 12.08 cm), indicating that the increase in plant height under T9 was not statistically significant. T9 exceeded T6 by only 0.25 cm (0.15%) and T3 by 1.52 cm (0.91%), showing that the three treatments receiving 120 kg N ha^{-1} produced very similar final plant heights. Thus, the results indicate a numerical trend toward greater plant height with higher N and S supply rather than a clear statistical separation among treatments. The tendency for taller plants under the higher nutrient combination may be associated with the roles of N and S in protein and amino-acid synthesis, meristematic activity, cell division, and cell enlargement. Similar responses to N and S nutrition in sunflower have been reported by Reddi Ramu and Maheswara Reddy (2003), Legha and Giri (1999), and Singh *et al.* (2000).

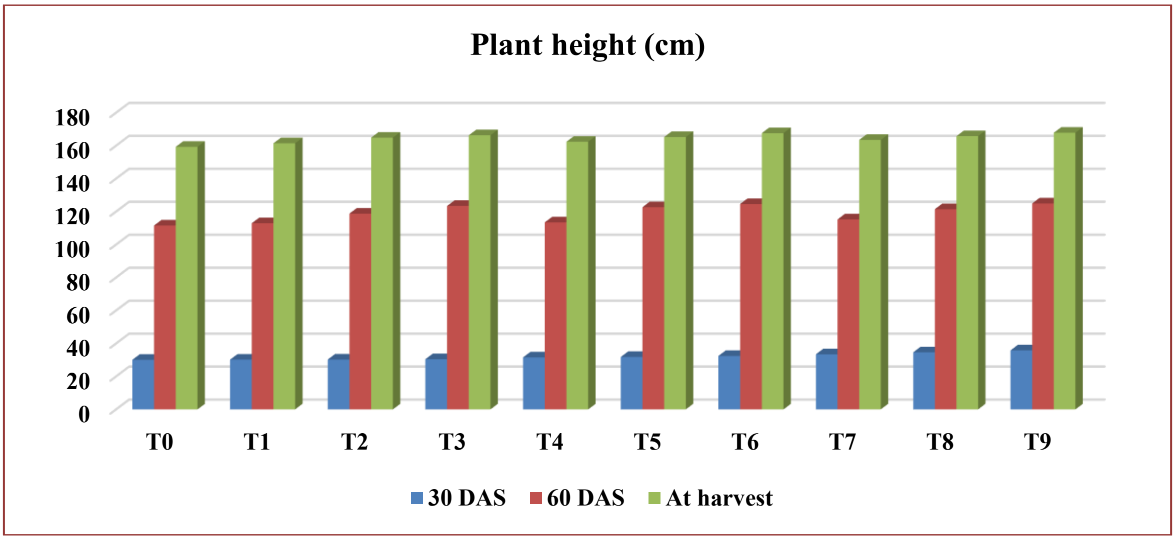

Fig. 1. Plant height of sunflower at 30 DAS, 60 DAS and harvest under different nitrogen and sulphur treatments

3.2 Number of Leaves/Plants

As shown in Table 1, at 60 DAS, the maximum number of leaves per plant (29.3) was recorded under T9 (N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1}), which was statistically at par with T6 (N @ 120 kg ha^{-1} + S @ 40 kg ha^{-1}) (28.7) and T3 (N @ 120 kg ha^{-1} + S @ 20 kg ha^{-1}) (28.3). The lowest number of leaves per plant (24.0) was observed under T0 (Control). Nitrogen and sulphur support the multiplication, elongation, and differentiation of cells, thereby enhancing vegetative growth by increasing plant height and the number of leaves (Pavani et al., 2013).

3.3 Dry Matter Accumulation (g/m^2)

As presented in Table 1, at harvest, the highest plant dry matter accumulation (43.86 g m^{-2}) was obtained under T9 (N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1}), which was statistically at par with T6 (N @ 120 kg ha^{-1} + S @ 40 kg ha^{-1}) (43.26 g m^{-2}) and T3 (N @ 120 kg ha^{-1} + S @ 20 kg ha^{-1}) (42.31 g m^{-2}). The lowest dry matter accumulation at harvest (35.43 g m^{-2}) was recorded under T0

(Control). Dry matter accumulation is closely linked to plant development and metabolic activities. Increased nitrogen and sulphur availability enhances plant growth, while nitrogen is essential for chlorophyll and cytochrome formation, which supports photosynthesis and, ultimately, increases dry matter production. The findings are similar to those of Pavani et al. (2013).

Table 1. Effect of nitrogen and sulphur levels on the growth parameters of sunflower

Treatment	Plant height (cm)	No. of leaves / plant	Dry matter g/m^2
T0: Control	159.26	24.0	35.43
T1: N@70kgha^{-1}+S@ 20kgha^{-1}	161.44	25.0	36.11
T2: N@90kgha^{-1}+S@ 20kgha^{-1}	164.82	26.5	40.38
T3: N@120kgha^{-1}+S@20kgha^{-1}	166.29	28.3	42.31
T4: N@70kgha^{-1}+S@40kgha^{-1}	162.34	25.7	36.84
T5: N@90kgha^{-1}+S@40kgha^{-1}	165.23	27.7	40.91
T6: N@120kgha^{-1}+S@40kgha^{-1}	167.56	28.7	43.26
T7: N@70kgha^{-1}+S@50kgha^{-1}	163.46	26.3	40.13
T8: N@90kgha^{1}+S@50kgha^{-1}	165.76	27.7	41.77
T9: N@120kgha^{1}+S@50kgha^{-1}	167.81	29.3	43.86
SEM±	5.45	0.50	2.24
CD(P=0.05)	12.08	1.46	7.94

Table 2. Effect of nitrogen and sulphur levels on yield and quality attributes of sunflower

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Head Diameter (cm)	oil content (%)	oil yield (kgha^{-1})
T0: Control	1650	3475	16.23	32.67	688.21
T1: N@70kg/ha+S@ 20kg/ha	1721	3582	16.53	33.44	686.11
T2: N@90kg/ha+S@ 20kg/ha	1746	3642	17.46	36.37	738.68
T3: N@120kg/ha+S@ 20kg/ha	1860	3835	18.54	35.21	786.24
T4: N@70kg/ha+S@ 40kg/ha	1766	3691	17.76	37.26	768.52
T5: N@90kg/ha+S@ 40kg/ha	1972	4068	19.13	38.42	811.42
T6: N@120kg/ha+S@ 40kg/ha	1995	4142	19.54	37.87	827.81
T7: N@70kg/ha+S@ 50kg/ha	1953	4025	18.97	39.79	972.42
T8: N@90kg/ha+S@ 50kg/ha	2023	4208	20.27	40.76	845.11
T9: N@120kg/ha+S@ 50kg/ha	2108	4365	20.64	40.34	853.33
SEM±	62.28	130.17	0.62	1.25	25.99
CD(P=0.05)	184.89	384.01	1.82	3.69	76.68

3.4 Head Diameter (cm)

As shown in Table 2, the largest head diameter (20.64 cm) was recorded under T9 (N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1}), which was statistically at par with T8 (N @ 90 kg ha^{-1} + S @ 50 kg ha^{-1}) (20.27 cm) and T6 (N @ 120 kg ha^{-1} + S @ 40 kg ha^{-1}) (19.54 cm). The smallest head diameter (16.23 cm) was observed under T0 (Control). Nitrogen stimulates chlorophyll formation, leaf area development, and biomass production, whereas sulphur facilitates protein formation and enhances enzyme activities. The proper combination of optimum levels of nitrogen and sulphur produced a larger capitulum, better pollination and seed setting, and thus increased the number of seeds per head. Moreover, proper nutrient availability during the filling period helped in storing more photosynthates within developing seeds and thus increased test weight. Therefore, balanced nutrition through nitrogen and sulphur played a vital role in improving the yield parameters of sunflower. The above observations corroborate the findings of Sarkar and Mallick (2009).

3.5 Seed Yield (kg/ha), Straw Yield

Seed and straw yield responses are presented in Table 2 and illustrated in Fig. 2. There was an improvement in seed and straw yield. Seed yield was significantly influenced by the various nitrogen and sulphur levels. The highest seed yield (2108kgha-1) was observed under Treatment-9 (N @ 120 kg/ha + S @ 50 kg/ha), followed by Treatment-8 (N @ 90 kg/ha +S @ 50 kg/ha) (2023 kg ha-1), Treatment-6 (N @ 120 kg ha-1 + S @ 40 kg ha-1) (1995 kg ha-1), and Treatment-5 (N @ 90 kg ha-1+S @ 40 kg ha-1) (1972 kg ha-1). The minimum seed yield (1650 kg ha-1) was observed in T0 (Control). There was a significant effect of the various nitrogen and sulphur levels on stover yield. The maximum straw yield (4365 kg/ha) was observed in Treatment-9 (N @ 120 kg ha-1 +S @50 kg ha-1), followed by Treatment-8 (N @ 90 kg ha-1 +S @ 50 kg ha-1) (4208 kg ha-1) and Treatment-6 (N @ 120 kg ha-1 + S @ 40 kg ha-1) (4142 kg ha-1). The minimum stover yield (3475 kg ha-1) was observed in T0 (Control). Increased nitrogen and sulphur treatment may result in higher straw yield due to increased crop growth, dry matter production, and biomass partitioning. Nitrogen, a crucial constituent of chlorophyll, proteins, and nucleic acids, promotes photosynthetic activity and vegetative development, thereby increasing biomass production. Sulphur helps synthesise sulphur-containing amino acids, proteins, enzymes, and oils, which promote efficient nutrient utilisation and metabolic activity. As a result, the combined availability of N and S favoured higher vegetative biomass and straw yield. The results were consistent with Pavani et al. (2013) and Shekhawat and Shivay (2008).

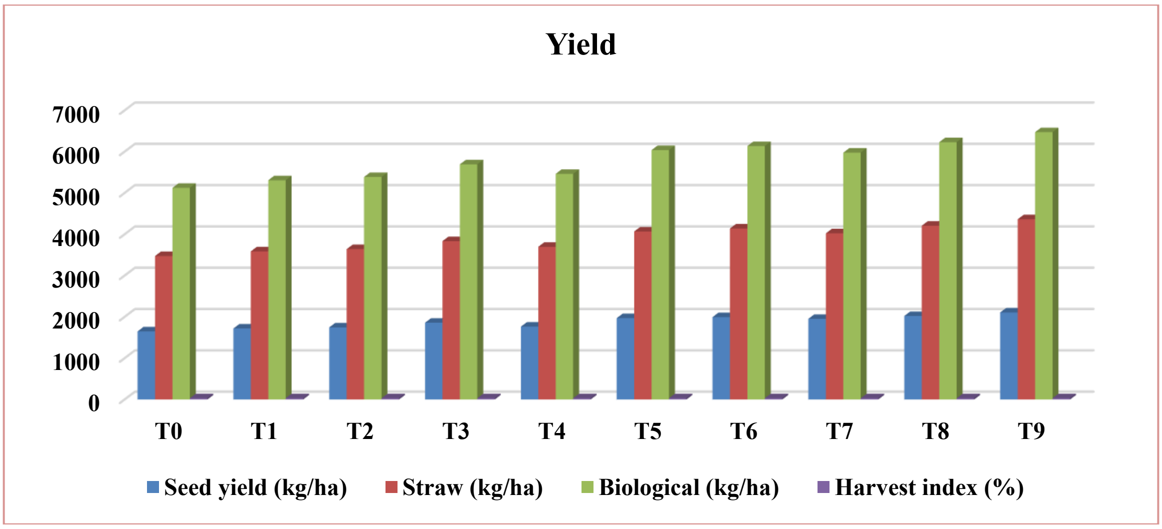

Fig. 2. Seed yield, straw yield, biological yield and harvest index of sunflower under different nitrogen and sulphur treatments

3.6 Quality Attributes of Sunflower

The observations concerning oil content and oil yield in response to various nitrogen and sulphur treatments are shown in Table 2. The findings show that there was a significant effect of the various nitrogen and sulphur treatments on both oil content and oil yield. Oil content was significantly influenced by the different nitrogen and sulphur levels. The highest oil content (40.76%) was recorded under T8 (N @ 90 kg ha^{-1} + S @ 50 kg ha^{-1}), which was statistically at par with T9 (N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1}) (40.34%) and T7 (N @ 70 kg ha^{-1} + S @ 50 kg ha^{-1}) (39.79%). The lowest oil content (32.67%) was observed under T0 (Control). Oil yield was significantly affected by the different nitrogen and sulphur levels. The maximum oil yield (853.33 kg ha^{-1}) was recorded under T9 (N @ 120 kg ha^{-1} + S @ 50 kg ha^{-1}), followed by T8 (N @ 90 kg ha^{-1} + S @ 50 kg ha^{-1}) (845.11 kg ha^{-1}) and T6 (N @ 120 kg ha^{-1} + S @ 40 kg ha^{-1}) (827.81 kg ha^{-1}). The minimum oil yield (688.21 kg ha^{-1}) was recorded under T0 (Control).

4. Conclusion

The study demonstrated that sunflower growth and productivity responded to combined nitrogen and sulphur application under the Central Plain Zone conditions of Uttar Pradesh. Among the evaluated treatments, N at 120 kg ha^{-1} + S at 50 kg ha^{-1} (T_9) recorded the highest plant height, number of leaves per plant, dry matter accumulation, head diameter, seed yield, stover yield, and biological yield. Oil concentration responded differently, with the highest oil content recorded under N at 90 kg ha^{-1} + S at 50 kg ha^{-1} (T_8). These results indicate that a higher nitrogen level with 50 kg S ha^{-1} was favourable for productivity, whereas a moderate nitrogen level with the same sulphur level was favourable for oil concentration. Within the conditions of this experiment, balanced nitrogen and sulphur nutrition was associated with improved crop performance. Accordingly, the treatment responses should be interpreted within the experimental conditions. Confirmation across additional seasons, locations, and sunflower genotypes is needed before broader recommendations are made.

5. Limitations

The study was conducted during a single Zaid season at a single site, using only the sunflower hybrid DRSH-1; thus, the findings may have limited application across different settings and genotypes. The study examined the short-term impacts of nitrogen and sulphur on sunflower production and quality, but not nutrient-use efficiency, residual nutrient effects, or long-term soil fertility changes. Additional multi-location and multi-season research is needed to corroborate the reported responses across a variety of agro-ecological situations.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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