International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM December 2025, 16(12): 01-07

Article AR6636

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2025.6636

# Effect of Integrated Neem-coated Urea and Nano-urea Strategies on the Growth and Yield of Sesame (*Sesamum indicum* L.)

**S. K. Patra, A. K. Dolai, Shubhadip Kar, Atanu Mahanty, Subham Chakraborty and Gurupada Saren**

Dept. of Agronomy, Institute of Agricultural Science, University of Calcutta, Ballygunge Circular Road, Kolkata, West Bengal (700 019), India

Open Access

**Corresponding** souvanpatra@gmail.com

0009-0006-6827-8246

## ABSTRACT

The present field experiment was carried out during pre-*kharif* season (February to May) for two consecutive years of 2024 and 2025 at Baruipur Experimental Farm, University of Calcutta, West Bengal, India to evaluate the replacement potential of neem-coated prilled urea (NCPU) with nano-urea in sesame (var. Suprava, CUMS-17). The randomized block design included 10 nitrogen management treatments, combining varied proportions of soil-applied NCPU with foliar nano-urea (4% N) or 2% urea sprays. Growth, yield attributes, and seed yield were recorded and statistically analyzed. Results showed significant effects of nitrogen management on plant height, dry matter accumulation (DMA), crop growth rate (CGR, 30–60 DAS), capsules plant$^{-1}$, seeds capsule$^{-1}$, and seed yield. The highest plant height (143.71 cm), DMA (609.28 g m$^{-2}$), CGR (8.28 g m$^{-2}$ day$^{-1}$), capsules plant$^{-1}$ (69.47), and seed yield (1.09 t ha$^{-1}$) were achieved with 100% RDN through split NCPU application. This was statistically at par with (75% NCPU+nano-urea spray at 45 DAS; yield: 1.07 t ha$^{-1}$), suggesting that partial soil-applied N replacement with nano-urea was feasible without yield loss. The study concluded that integrating 75% RDN via NCPU with a single nano-urea spray could sustain yields comparable to full NCPU application, offering a resource-efficient, sustainable nitrogen management option for sesame in West Bengals's pre-*kharif* season.

**KEYWORDS:** Suprava, nitrogen management, NCPU, resource-efficient, nano-urea

***Citation* (VANCOUVER):** Patra et al., Effect of Integrated Neem-coated Urea and Nano-urea Strategies on the Growth and Yield of Sesame (*Sesamum indicum* L.). *International Journal of Bio-resource and Stress Management*, 2025; 16(12), 01-07. HTTPS://DOI.ORG/10.23910/1.2025.6636.

***Copyright:*** © 2025 Patra et al. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, that permits unrestricted use, distribution and reproduction in any medium after the author(s) and source are credited.

***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

***Conflict of interests:*** The authors have declared that no conflict of interest exists.

RECEIVED on 15th August 2025 RECEIVED in revised form on 06th November 2025 ACCEPTED in final form on 24th November 2025 PUBLISHED on 02nd December 2025

# 1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the earliest domesticated oilseed crops, valued for its nutritional richness and ability to thrive in semi-arid environments, making it integral to both traditional and modern agriculture (Bedigian, 2010). Globally, sesame is cultivated on about 12.97 m ha (Sanni et al., 2024) and is often termed the "Queen of Oilseeds" for its exceptionally high oil content, up to 63%, which exceeds sunflower (45%), groundnut (45–56%), soybean (20%), and rapeseed (40%) (Teklu et al., 2021). Its seeds contain 19–25% protein, high levels of calcium, magnesium, phosphorus, zinc, and iron, and unique lignan antioxidants such as sesamin, sesamolin, and sesamol that enhance oxidative stability and human health benefits (Mostashari and Mousavi Khaneghah, 2024; Langyan et al., 2022; Wan et al., 2023; Dossou et al., 2023). India remains the leading sesame producer, with major cultivation in West Bengal, Madhya Pradesh, Gujarat, and Uttar Pradesh. In 2022–23, production reached 8.02 lakh t, with West Bengal contributing 0.251 mt (31% of national output) (Anonymous, 2024). Apart from its edible oil value, sesame cake contains about 32% crude protein and 8–10% residual oil, making it a good livestock feed (Kabinda et al., 2022). Sesame is also linked to antihypertensive, anticancer, antioxidant, and lipid-lowering properties (Mili et al., 2021; Majdalawieh and Mansour, 2019). Yet, productivity in India remains low due to rainfed farming, indeterminate growth, capsule shattering, and poor adoption of improved practices (Kefale and Wang, 2022; Qureshi et al., 2022; Yadav et al., 2022). Nutrient management, particularly nitrogen, is a major constraint. Nitrogen strongly influences vegetative growth, dry matter accumulation, and seed yield, but its efficient use in sesame is limited by leaching and poor synchronization with crop demand (Maqsood et al., 2016; Rosolem et al., 2017). While conventional urea dominates, its low use efficiency causes environmental and economic concerns. Neem-coated prilled urea (NCPU) offers a slow-release alternative, ensuring better nutrient synchrony and reduced losses (Salam et al., 2020; Bellaloui et al., 2018). More recently, nano urea (4% N, 20–50 nm particles) has emerged as an innovative foliar fertilizer with reported uptake efficiencies above 80% (Anonymous, 2025). Field studies show nano urea integrated with conventional nitrogen increases wheat and black gram yields by 5–9 % (Islam et al., 2023; Tripathi et al., 2025). In sesame, promising outcomes have been observed where nano urea sprays combined with soil-applied nitrogen sustained yields and improved profitability (Meena et al., 2024; Mandal et al., 2023; Kumar et al., 2023; Singh et al., 2023). Despite these advances, research on integrating nano urea with conventional nitrogen under sesame-based systems in eastern India is scarce. West Bengal, though a leading sesame-growing state, records yields below the global average, largely due to rainfed conditions and suboptimal nutrient use. Neem-coated urea is widely adopted, but its partial substitution with nano urea remains underexplored, especially during the pre-*kharif* season when nutrient leaching and climatic stresses are prevalent. This knowledge gap highlights the need for evaluating resource-efficient nitrogen strategies that sustain productivity while reducing fertilizer inputs. Therefore, this two-year field experiment was undertaken to assess the replacement potential of neem-coated prilled urea with nano urea sprays in sesame (var. Suprava, CUMS-17) under the pre-*kharif* season of West Bengal. The objective was to evaluate the effects of different nitrogen regimes on growth, yield attributes, and seed yield, aimed to identify sustainable nitrogen management practices that improve nitrogen use efficiency.

# 2. MATERIALS AND METHODS

## 2.1. Experimental period and location

The experiment was conducted during pre-*kharif* season (February to May) for two consecutive years of 2024 and 2025 at the Baruipur experimental farm of University of Calcutta, South 24 parganas, West Bengal (88°26'E; 22°22'N; 9 m altitude), to evaluate the suitable replacement of neem coated urea with nano urea. The temperature during the cropping period was in between 19°C to 36°C with an average rainfall of 0.7–120 mm and an average humidity of 72–88%. The soil of the experimental site was clay loam in texture having pH of 5.7, organic carbon 0.64%, available nitrogen 302 kg ha$^{-1}$, phosphate 24.9 kg ha$^{-1}$ and potassium 139.7 kg ha$^{-1}$.

## 2.2. Experimental design and treatment details

The experiment was laid out with 10 treatments replicated thrice in Randomized block design (RBD). A sesame variety Suprava 'CUMS-17' (85–90 days maturity) was sown in line by following a row to row spacing of 30 cm and plant to plant spacing of 10 cm. The treatments followed were $T_1$: Complete N through neem coated prilled urea (50% as basal+25% at 20 DAS+25% at early flowering); $T_2$: 50% recommended N through neem coated prilled urea as basal+4 ml l$^{-1}$ nano urea sprays at 30 DAS and 45 DAS; $T_3$: 50% recommended N through neem coated prilled urea as basal+2% urea sprays at 30 DAS and 45 DAS; $T_4$: N through nano urea only-2 sprays (4 ml l$^{-1}$ spray at 30 and 45 DAS); $T_5$: N through 2% urea spray only-2 sprays (30 DAS and 45 DAS); $T_6$: 75% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+4 ml l$^{-1}$ nano urea spray at 45 DAS; $T_7$: 75% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+2% urea spray at 45 DAS; $T_8$: 50% recommended N through neem coated prilled urea (50% N as basal+50%

N at 30 DAS)+4 ml $l^{-1}$ nano urea spray at 45 DAS; $T_9$: 50% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+2% urea spray at 45 DAS; $T_{10}$: Control (No N); N:Nitrogen; DAS: Days after sowing.

### 2.3. *Package and practices*

The recommended dose of fertilizer (RDF) was 60 kg Nitrogen $ha^{-1}$, 30 kg Phosphorus $ha^{-1}$ and 30 kg Potassium $ha^{-1}$. Fertilizer doses were applied as per treatment. Other recommended package of practices was followed to raise the crop.

### 2.4. *Observations and procedure of data recorded*

The biometric observations for different growth attributes, yield attributes and yield of sesame were recorded at regular interval. Plant height, Number of branches $plant^{-1}$ at harvest, dry matter accumulation, crop growth rate was measured and calculated. Whereas, at harvest, yield components like number of capsule $plant^{-1}$, number of seed $capsule^{-1}$, Test weight, seed yield, were measured and recorded for estimation of yield of sesame.

### 2.5. *Methods of statistical analysis*

The data were analyzed by following Analysis of Variance (ANOVA) technique and mean difference were adjusted by the multiple comparison test (Gomez and Gomez, 1984). The significance of different source of variance was tested by error mean square of Fisher's 'F' test at Probability level 0.05. Fisher and Yate's tables were consulted for the determination of critical difference at $p$=0.05 level of significance. The value of standard error of mean (SEm±) and the critical difference (CD) to compare the difference between the treatment means.

## 3. RESULTS AND DISCUSSION

### 3.1. *Effect of nitrogen management on growth attributes of sesame*

The pooled analysis over two years revealed that nitrogen management significantly influenced sesame growth parameters such as plant height, dry matter accumulation, and crop growth rate (CGR), whereas number of branches $plant^{-1}$ remained statistically non-significant (Table 1).

The tallest plants at harvest were recorded in $T_1$ (143.71 cm), which was statistically at par with $T_6$ (136.94 cm), but significantly taller than all other treatments. The enhanced plant height under these treatments could be attributed to timely and adequate nitrogen supply, which promoted vegetative vigor and internodal elongation. Dry matter accumulation followed a parallel trend: $T_1$ (609.28 g $m^{-2}$) and $T_6$ (597.90 g $m^{-2}$) were statistically at par and superior to all other treatments. This might be attributed to increased canopy development, enhanced nitrogen assimilation, and improved sunlight interception, leading to greater photosynthetic biomass production. Similarly, a Punjab-based experiment found that full soil-applied urea achieved the highest heights across multiple growth stages, though 25% nanourea foliar spray also significantly improved height over lower sprays and control Singh et al. (2025), These findings corroborate the current observation that split basal N, especially when coupled with foliar nano-urea, enhanced taller sesame plants. It was also emphasized that dry matter accumulation was positively influenced by synchronized nitrogen release aligned with critical crop stages, as nitrogen was integrated to chlorophyll biosynthesis and photosynthetic efficiency (Maqsood et al., 2016).

Regarding crop growth rate (30–60 DAS), the highest CGR was observed in $T_1$ (8.28 g $m^{-2}$ $day^{-1}$), which was statistically at par with $T_6$ (7.98 g $m^{-2}$ $day^{-1}$) and $T_7$ (7.67 g $m^{-2}$ $day^{-1}$). The improved CGR during this period was indicative of vigorous vegetative growth, a function of adequate nitrogen availability. CGR at this stage reflected biomass accumulation rate during canopy expansion a period when nitrogen uptake was typically maximal (Rosolem et al., 2017). The reduced CGR under $T_4$ and $T_5$, which relied solely on foliar sprays, suggested that exclusive foliar application might not satisfy the root-zone N demand during rapid biomass expansion, a point also mentioned by El-Sherif (2016) in Egyptian sesame systems. This also corresponded with Meena et al. (2024), where sesame received significant biomass gains from combined nano-fertilizer and conventional urea demonstrating increased dry matter accumulation and profitability. In contrast, CGR from 60 DAS to harvest showed, the highest value was found in $T_6$ (11.48 g $m^{-2}$ $day^{-1}$) and all other treatments remained statistically at par except the foliar only ($T_4$ and $T_5$) and control ($T_6$) treatments, suggesting that a combination of basal and later-stage nitrogen availability supported reproductive biomass production. This trend aligned with the findings of Damdar et al. (2015) and Gebremariam (2015), who emphasized the role of late-stage nitrogen in enhancing pod filling and seed development.

Branch production, while not statistically different across treatments, was numerically highest under $T_1$ (4.04) and $T_6$ (4.01). Gebremariam (2015) also reported that split application of nitrogen enhanced axillary meristem activity, which might contribute to better branching, a vital yield component in sesame.

It was observed that $T_{10}$ (control) consistently recorded the lowest values across all growth attributes. This clearly highlighted the necessity of nitrogen in sesame for promoting vegetative and early reproductive growth that without any N, vegetative growth remained minimal, with shorter and sparser plants correlating researches of Salam et al. (2020); Bellaloui et al. (2018) Foliar-only treatments

Table 1: Effect of nitrogen management on growth, yield attributes and seed yield of sesame at different growth stages (Pooled data)

| Treatment | Plant height at harvest (cm) | No. of branches plant$^{-1}$ at harvest | Dry matter accumulation at harvest (g m$^{-2}$) | Crop growth rate at 30–60 DAS (g m$^{-2}$ day$^{-1}$) | Crop growth rate at 60 DAS-at harvest (g m$^{-2}$ day$^{-1}$) | Capsule plant$^{-1}$ | Seed capsule$^{-1}$ | Test weight (g) | Seed yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 143.71 | 4.04 | 609.28 | 8.28 | 11.32 | 69.47 | 53.50 | 2.92 | 1.09 |
| $T_2$ | 127.49 | 3.96 | 495.35 | 5.64 | 10.38 | 63.28 | 50.41 | 2.81 | 0.93 |
| $T_3$ | 127.07 | 3.98 | 489.37 | 5.41 | 10.43 | 62.07 | 50.27 | 2.80 | 0.90 |
| $T_4$ | 99.77 | 4.00 | 399.88 | 4.24 | 8.73 | 56.78 | 44.72 | 2.66 | 0.71 |
| $T_5$ | 106.30 | 3.98 | 364.36 | 4.04 | 7.83 | 52.90 | 49.36 | 2.76 | 0.68 |
| $T_6$ | 136.94 | 4.01 | 597.90 | 7.98 | 11.48 | 66.12 | 53.45 | 2.89 | 1.07 |
| $T_7$ | 133.61 | 3.97 | 550.72 | 7.67 | 10.23 | 63.68 | 51.64 | 2.80 | 1.00 |
| $T_8$ | 121.61 | 3.66 | 484.04 | 5.15 | 10.55 | 59.42 | 51.66 | 2.86 | 0.88 |
| $T_9$ | 121.57 | 3.29 | 480.83 | 5.07 | 10.56 | 57.70 | 51.15 | 2.80 | 0.86 |
| $T_{10}$ | 95.04 | 3.66 | 291.51 | 3.80 | 5.59 | 49.82 | 47.67 | 2.49 | 0.55 |
| SEm± | 3.24 | 0.40 | 14.61 | 0.22 | 0.49 | 1.35 | 1.03 | 0.03 | 0.03 |
| CD ($p$=0.05) | 9.31 | NS | 41.91 | 0.63 | 1.41 | 3.88 | 2.96 | 0.09 | 0.07 |

$T_1$: Complete N through neem coated prilled urea (50% as basal+25% at 20 DAS+25% at early flowering); $T_2$: 50% recommended N through neem coated prilled urea as basal+4 ml l$^{-1}$ nano urea sprays at 30 DAS and 45 DAS; T3: 50% recommended N through neem coated prilled urea as basal+2% urea sprays at 30 DAS and 45 DAS; T4: N through nano urea only-2 sprays (4 ml l$^{-1}$ spray at 30 and 45 DAS); T5: N through 2% urea spray only-2 sprays (30 DAS and 45 DAS); $T_6$: 75% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+4 ml l$^{-1}$ nano urea spray at 45 DAS; $T_7$: 75% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+2% urea spray at 45 DAS; $T_8$: 50% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+4 ml l$^{-1}$ nano urea spray at 45 DAS; $T_9$: 50% recommended N through neem coated prilled urea (50% N as basal+50% N at 30 DAS)+2% urea spray at 45 DAS; $T_{10}$: Control (No N); N:Nitrogen; DAS: Days after sowing

($T_4$ and $T_5$) recorded lower performance across parameters, reinforcing the idea that foliar nitrogen alone, particularly nano urea or 2% conventional urea, cannot totally substitute for a full soil-applied nitrogen regime.

### *3.2. Effect of nitrogen management on yield attributes of sesame*

The pooled data over two years showed that nitrogen management treatments had a significant effect on key yield attributes of sesame, number of capsules plant$^{-1}$ and seeds capsule$^{-1}$, test weight (Table 1).

Across these parameters, $T_1$ Complete N through neem coated prilled urea (50% as basal+25% at 20 DAS+25% at early flowering) consistently recorded the highest values 69.47 capsules plant$^{-1}$, 53.50 seeds capsule$^{-1}$, and 2.92 g test weight, all significantly superior to most treatments. $T_6$ ranked next, with values statistically at par with $T_1$ for 53.45 seeds capsule$^{-1}$, 2.89 g test weight and 66.12 capsules plant$^{-1}$. Enhanced capsule setting in $T_1$ and $T_6$ could be attributed to balanced and timely nitrogen availability during flowering, promoting axillary bud differentiation, flower development, and pod retention. This aligned with Salam et al. (2020), who reported higher capsules plant$^{-1}$ with increased nitrogen, enhancing photosynthate production and allocation to reproductive sinks. For seeds capsule$^{-1}$, superior treatments supplied nitrogen during critical flowering and seed development stages, improving pollen fertility, fertilization, and seed set, consistent with El-Sherif (2016), Gebremariam (2015), and Hassan et al. (2018), who emphasized the role of reproductive-phase nitrogen in seed filling and seed count.

The test weight, though numerically highest under $T_1$ (2.92 g) and $T_6$ (2.89 g), but not differed too much with all other treatments. This indicated that genotypic factors also have an influence with nitrogen levels, primarily control seed mass in sesame. A conclusion by Khan et al. (2016), who also observed linear increase in test weight with relation to increasing level of nitrogen.

Overall, the superior performance of $T_1$ highlighted the importance of synchronizing nitrogen supply with crop demand. The results also confirm that $T_6$, which integrated 75% neem-coated prilled urea with a nano urea spray at 45 DAS, was equally effective in enhancing yield attributes, providing a potential strategy for partial nitrogen substitution without yield penalty. In contrast, treatments relying exclusively on foliar nutrition ($T_4$ and $T_5$) or reduced soil-applied nitrogen ($T_8$ and $T_9$) demonstrated moderate to poor performance. The control treatment $T_{10}$ consistently produced the lowest values across all yield parameters, reinforcing nitrogen's vital role in reproductive development, reflecting that foliar N alone did not satisfy the nitrogen demand during capsule initiation and seed growth stages. (Sarkar et al., 2025); (Khan et al., 2016).

### *3.3. Effect of nitrogen management on seed yield of sesame*

Seed yield differed significantly among treatments confirming that nitrogen management markedly impacts economic output in sesame (Table 1). Treatment $T_1$, which received 100% recommended dose of neem-coated prilled urea in split soil application, produced the highest pooled yield of 1.09 t $ha^{-1}$. Treatment $T_6$, combining 75% soil-applied N with a nano-urea foliar spray, statistically at par at 1.07 t $ha^{-1}$, indicating that strategic foliar supplementation could nearly match full-dose soil application. This outcome corroborated field trial by Singh et al. (2023), that incremental nitrogen rates significantly boost sesame seed yield, especially when split applied to match crop demand across growth stages.

These treatments performed better than foliar-only ($T_4$, $T_5$: 0.71–0.68 t $ha^{-1}$) or no nitrogen ($T_{10}$: 0.55 t $ha^{-1}$) treatments, underscoring that a minimum soil-applied N component was essential for achieving appreciable yields. Soil-applied nitrogen played a vital role in supporting early vegetative growth and capsule formation, which foliar application alone could not sustain. Adequate soil N ensured continuous nutrient uptake and promoted photosynthetic activity, assimilate translocation, and efficient seed filling, ultimately leading to superior yield fulfillment in sesame. Adisu et al. (2020) concluded that the combined effect of nitrogen and phosphorus fertilization significantly enhanced the final yield and critical yield components of sesame, underscoring that optimizing the soil nutrient matrix was essential for maximizing biological efficiency. Bellaloui et al. (2018) specifically found that increasing soil nitrogen application rates positively correlated with a substantial increase in overall sesame seed yield, affirming the direct link between sustained N supply and maximized harvestable output. Furthermore, Salam et al. (2020) demonstrated that varying levels of soil-applied nitrogen obtained beneficial effects on the vegetative growth characteristics and the final yield metrics.

## 4. CONCLUSION

Substituting 25% of the recommended nitrogen dose from neem-coated prilled urea (NCPU) with a single foliar spray of nano-urea at 45 DAS maintained sesame yields comparable to full NCPU application. The integrated treatment significantly improved plant growth, dry matter accumulation, and yield attributes. This strategy had improved nitrogen use efficiency through an appropriate partial substitution of soil-applied nitrogen.

## 5. REFERENCES


Adisu, T., Anbesse, B., Tamene, D., 2020. Effect of nitrogen and phosphorus on yield and yield components of sesame (*Sesamum indicum* L.) at Kamashi Zone of Benshangul Gumuz under balanced fertilizer. Advanced Techniques in Biology & Medicine 8(4), 276–281. Available at: https://www.longdom.org/open-access/effect-of-nitrogen-and-phosphorus-on-yield-and-yield-components-of-sesame-sesamum-indicum-l-at-kamashi-zone-of-benshangul-gumuz-un-59135.html.

Anonymous, 2024. Sesame seed–performance review (FY 2023–24). Retrieved from: https://ncdex.com/public/uploads/downloads/Sesame%20Seed_Performance%20Review%20FY%202023-24_1719394550.pdf. Retrieved on: 2nd July, 2025.

Anonymous, 2025. Nano urea (Liquid) fertilizer. Retrieved from: https://nano-urvarak.iffco.in/. Retrieved on: 10th July, 2025.

Bedigian, D., 2010. Sesame: the genus sesamum (1st Edn.). CRC press, Boca Raton, 556pp. Available at: https://www.taylorfrancis.com/books/mono/10.1201/b13601/sesame-dorothea-bedigian.

Bellaloui, N., Abbas, H.K., Wayne Ebelhar, M., Mengistu, A., Mulvaney, M.J., Accinelli, C., Thomas Shier, W., 2018. Effect of increased nitrogen application rates and environment on protein, oil, fatty acids, and minerals in sesame (*Sesamum indicum*) seed grown under Mississippi Delta conditions. Food and Nutrition Sciences 9(9), 1112–1135. Available at: https://www.scirp.org/journal/paperinformation?paperid=87657.

Damdar, R.R., Bhale, V.M., Deshmukh, K.M., 2015. Yield, growth and quality of summer sesame (*Sesamum indicum* L.) as influenced by irrigation and nitrogen levels. International Journal of Agricultural Sciences 11(2), 301–306. Available at: https://doi.org/10.15740/HAS/IJAS/11.2/301-306.

Dossou, S.S., Kof Xu, F.T., Dossa, K., Rong, Z., Zhao, Y.Z., Wang, L.H., 2023. Antioxidant lignans sesamin and sesamolin in sesame (*Sesamum indicum* L.): a comprehensive review and future prospects. Journal of Integrative Agriculture 22(1), 14–30. Available at: https://doi.org/10.1016/j.jia.2022.08.097.

El-Sherif, A.M.A., 2016. Sesame (*Sesamum indicum* L.) yield and yield components influenced by nitrogen and foliar micronutrient applications in the Fayoum region, Egypt. Egyptian Journal of Agronomy 38(3), 355–367. Available at: https://journals.ekb.eg/article_1274_d5183b300978a315e7bf6a11de92ed71.pdf.

Gebremariam, G., 2015. Growth, yield and yield component of sesame (*Sesamum indicum* L.) as affected by timing of nitrogen application. Journal of Biology, Agriculture and Healthcare 5(5), 1–7. Available at: https://core.ac.uk/download/pdf/234660793.pdf.

Gomez, K.A., Gomez, A.A., 1984. Statistical procedures for agricultural research. John wiley & sons, 680pp. Available at: https://www.scirp.org/reference/referencespapers?referenceid=2253909.

Hassan, S.A., Haq, M.E., Ahmed, M., Rahman, M.M., Paul, A.K., 2018. Effect of combined application of nitrogen and phosphorus on the yield of sesame. International Journal of Plant & Soil Science 25(4), 1–6. Available at: https://doi.org/10.9734/IJPSS/2018/44830.

Islam, M.Z.A., Alim, S.M.A., Hoque, M.M., Islam, M.M., Adhikary, S., 2023. Effect of nano urea foliar spray on yield and yield attributes of black gram (*Vigna mungo* L.). Journal of Agroforestry and Environment 16(1), 64–66. Available at: https://doi.org/10.55706/jae1609.

Kabinda, J., Madzimure, J., Murungweni, C., Mpofu, I.D.T., 2022. Significance of sesame (*Sesamum indicum* L.) as a feed resource towards small-ruminant animal production in Southern Africa: A review. Tropical Animal Health and Production 54(2), 106. Available at: https://doi.org/10.1007/s11250-022-03062-5.

Kefale, H., Wang, L., 2022. Discovering favorable genes, QTLs, and genotypes as a genetic resource for sesame (*Sesamum indicum* L.) improvement. Frontiers in Genetics 13. Available at: https://doi.org/10.3389/fgene.2022.1002182.

Khan, N., Khalil, S.K., Amanullah Ali, A., Ullah, Z., Ali, M., 2016. Effect of nitrogen and sulfur on yield and yield components of sesame (*Sesamum indicum* L.) in calcareous soil. Pure and Applied Biology 5(3), 471–475. Available at: https://doi.org/10.19045/bspab.2016.50061

Kumar, A., Ram, H., Kumar, S., Kumar, R., Yadav, A., Gairola, A., Kumar, V., Sharma, T., 2023. A comprehensive review of nano-urea vs. conventional urea. International Journal of Plant & Soil Science 35(23), 32–40. Available at: https://doi.org/10.9734/IJPSS/2023/v35i234212.

Langyan, S., Yadava, P., Sharma, S., Gupta, N.C., Bansal, R., Yadav, R., Kalia, S., Kumar, A., 2022. Food and nutraceutical functions of sesame oil: an underutilized crop for nutritional and health bene ts. Food Chemistry 389, 132990. Available at: https://doi.org/10.1016/j.foodchem.2022.132990.

Majdalawieh, A.F., Mansour, Z.R., 2019. Sesamol, a major lignan in sesame seeds (*Sesamum indicum*): anti-cancer properties and mechanisms of action. European Journal of Pharmacology 855, 75–89. Available at: https://doi.org/10.1016/j.ejphar.2019.05.008.

Mandal, U.K., Mal, S., Naiya, A.K., Ghosh, A., Nayak, D.B., Digar, S., Bhardwaj, A.K., 2023. Nano-urea for vegetable cultivation in coastal West Bengal. Journal of the Indian Society of Coastal Agricultural Research 41(1). Available at: https://doi.org/10.54894/JISCAR.41.1.2023.135357.

Maqsood, M.A., Awan, U.K., Aziz, T., Arshad, H., Ashraf, N., Ali, M., 2016. Nitrogen management in calcareous soils: Problems and solutions. Pakistan Journal of Agricultural Sciences 53(1), 79–95. Available at: https://api.pakjas.com.pk/downloadPaper/2539.pdf.

Meena, L.C., Ramawat, N., Shukla, U.N., Raiger, P.R., Choudhary, S., Kumar, R., Kumar, N., 2024. Productivity and profitability of sesame (*Sesamum indicum* L.) as influenced by conjoint application of nano fertilizers with conventional urea. Annals of Agricultural Research 45(3), 253–260. Available at: https://epubs.icar.org.in/index.php/AAR/article/view/162898.

Mili, A., Das, S., Nandakumar, K., Lobo, R., 2021. A comprehensive review on *Sesamum indicum* L.: botanical, ethnopharmacological, phytochemical, and pharmacological aspects. Journal of Ethnopharmacology 281, 114503. Available at: https://doi.org/10.1016/j.jep.2021.114503.

Mostashari, P., Mousavi Khaneghah, A., 2024. Sesame seeds: a nutrient-rich superfood. Foods 13(8), 1153.

Qureshi, M., Langham, D., Lucas, S.J., Uzun, B., Yol, E., 2022. Breeding history for shattering trait in sesame: classic to genomic approach. Molecular Biology Reports 49(7), 7185–7194. Available at: https://doi.org/10.1007/s11033-022-07636-2.

Rosolem, C.A., Ritz, K., Cantarella, H., Galdos, M.V., Hawkesford, M.J., Whalley, W.R., Mooney, S.J., 2017. Enhanced plant rooting and crop system management for improved N use efficiency. In: Sparks, D.L. (Ed.), Advances in agronomy, 146). Academic Press, 205–239. Available at: https://doi.org/10.1016/bs.agron.2017.07.002.

Salam, M.A., Khatun, A., Kader, M.A., 2020. Effect of levels of nitrogen on the growth and yield of sesame (*Sesamum indicum* L.) cultivars. Journal of the Bangladesh Agricultural University 18(4), 949–955.

Available at: https://www.cabidigitallibrary.org/doi/pdf/10.5555/20210025033.

Sanni, G.B.T.A., Ezin, V., Chabi, I.B., Missihoun, A.A., Florent, Q., Hamissou, Z., Ahanchede, A., 2024. Production and achievements of *Sesamum indicum* industry in the world: Past and current state. Oil Crop Science 9(3), 187–197. Available at: https://doi.org/10.1016/j.ocsci.2024.06.006.

Sarkar, S., Pradhan, A., Raj, K., Mohanta, A., Singh, R., 2025. Effect of nitrogen and plant growth regulator on yield and economics of sesame (*Sesamum indicum* L.). International Journal of Advanced Biochemistry Research 9(5), 870–872. Available at: https://doi.org/10.33545/26174693.2025.v9.i5k.4437.

Singh, S.D., Jadhav, D.B., Patil, S.S., Hari, A., Aggarwal, A., 2023. Studies on growth and yield of sesame (*Sesamum indicum*) as influenced by different levels of nitrogen and nano urea. Ecology, Environment and Conservation 29(4), 1696–1699. Available at: http://doi.org/10.53550/EEC.2023.v29i04.038.

Singh, S.D., Patil, S.S., Jadhav, D.B., Birunagi, S.M., Karmakar, K., Saini, N., Hari, A., 2025. Response of soil applied urea and foliar applied nano urea on the growth, yield and quality of *kharif* sesame (*Sesamum indicum*) under the central plain agro-climatic zone of Punjab. Agricultural Science Digest 1–6. Available at: https://doi.org/10.18805/ag.D-5886.

Teklu, D.H., Shimelis, H., Tesfaye, A., Mashilo, J., Zhang, X., Zhang, Y., Dossa, K., Shayanowako, A.I.T., 2021. Genetic variability and population structure of Ethiopian sesame (*Sesamum indicum* L.) germplasm assessed through phenotypic traits and simple sequence repeats markers. Plants 10(6). Available at: https://doi.org/10.3390/plants10061129.

Tripathi, S.C., Kumar, N., Venkatesh, K., 2025. Nano urea's environmental edge and economic efficacy in boosting wheat grain yield across diverse Indian agro-climates. Scientific Reports 15(1), 3598. Available at: https://www.nature.com/articles/s41598-024-83616-9.

Wan, Y., Zhou, Q., Zhao, M., Hou, T., 2023. Byproducts of sesame oil extraction: composition, function, and comprehensive utilization. Foods 12(12), 2383. Available at: https://doi.org/10.3390/foods12122383.

Yadav, R., Kalia, S., Rangan, P., Pradheep, K., Rao, G.P., Kaur, V., Pandey, R., Rai, V., Vasimalla, C.C., Langyan, S., Sharma, S., Thangavel, B., Rana, V.S., Vishwakarma, H., Shah, A., Saxena, A., Kumar, A., Singh, K., Siddique, K.H.M., 2022. Current research trends and prospects for yield and quality improvement in sesame, an important oilseed crop. Frontiers in Plant Science 13. Available at: https://doi.org/10.3389/fpls.2022.863521.