**Influence of nitrogen and sulphur on growth and yield of *kharif* cotton**

**Abstract:**

 A field experiment was conducted during 2022-23 and 2023-24 at Anand Agricultural University, Gujarat, to evaluate the effect of nitrogen and sulphur on cotton. Results showed that growth parameters like plant height, monopodial and sympodial branches/plant; yield attributes such as number of bolls/plant, seed cotton yield, and stalk yield were higher under application of 75% RDN + 25% FYM and were statistically similar to application of 75% RDN + 25% neem cake. Sulphur application significantly influenced yield and quality, with the best results under application of 40 kg S/ha, which was at par with application of 20 kg S/ha. Higher seed cotton yield was recorded under 75% RDN + 25% FYM + 40 kg S/hatreatment combination, closely followed by 75% RDN + 25% FYM + 20 kg S/ha and 75% RDN + 25% neem cake + 40 kg S/ha treatments combinations, indicating a significant interaction effect between nitrogen and sulphur treatments.

**Key word**: Yield, Nitrogen, Sulphur and Cotton

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**INTRODUCTION**

 Cotton (Gossypium hirsutum L.) is a globally significant natural fiber crop, playing a vital role in agriculture, industry, and the economy, particularly in India (Constable & Bange, 2015). As the world’s leading cash crop, it is primarily cultivated for fiber and oilseed production, contributing approximately 25% of global fiber output (Dong *et al*., 2010). In India, cotton ranks second only to food grains in economic importance and is often referred to as "White Gold" due to its high commercial value (Patel *et al*., 2016).

 Nitrogen, phosphorus, and potassium are essential nutrients for crop production, with nitrogen being the most crucial and expensive input. It plays a key role in chlorophyll synthesis, protein formation, and overall crop growth. Meanwhile, sulphur deficiency has become increasingly common due to the adoption of high-yielding crop varieties that deplete soil sulphur. The reduced use of sulphur-containing fertilizers has further contributed to its scarcity, negatively impacting crop productivity and quality.

**MATERIAL AND METHOD**

A field experiment was conducted during 2022–23 and 2023–24 seasons at Plot No. 17–A, Regional Research Station, Anand Agricultural University, Anand (Gujarat), to study effect of nitrogen and sulphur on growth and yield of cotton under middle Gujarat conditions. The soil was loamy sand in texture, alkaline in reaction, and normal in salinity, with low organic carbon and available nitrogen, while available P₂O₅, K₂O, and sulphur were at medium levels. The cotton variety GTHV 13/28 was grown to evaluate to using a Factorial Randomized Block Design (FRBD) with five nitrogen sources: N1 (100 % RDN), N2 (75 % RDN + 25 % through FYM), N3 (75 % RDN and 25 % through neem cake), N4 (50% RDN + 25% through FYM + Bio NPK consortium) and N5 (50% RDN + 25% through neem cake + Bio NPK consortium). Additionally, three sulphur levels were tested: S1 (0 kg S/ha), S2 (20 kg S/ha) and S3 (40 kg S/ha). The experiment consisted of 15 treatment combinations, replicated three times. Nitrogen was applied using urea in opened furrows, while bentonite sulphur was used as the sulphur source. Cotton plucking began with the border row plants, followed by harvesting seed cotton from each net plot, which was weighed and recorded. The total seed cotton yield in kg/ha was calculated by summing the yields from two plucking. Cotton was sown on June 22, 2022, and June 27, 2023, as part of the cropping sequence.

**RESULT AND DISCUSSION**

**Effect of nitrogen on growth and yield and yield attributes**

 Application of nitrogen had no significant effect on plant population (Table1) at 15 DAS and at harvest; and seed index (Table 4) during 2022-23, 2023-24, and pooled analysis, Moreover, nitrogen application significantly influenced cotton growth and yield. Plant height (Table 1), as well as number of monopodial (Table 2) and sympodial (Table 3) branches/plant, increased notably at different growth stages. Yield attributes (Table 4) such as number of bolls/plant, seed cotton yield and stalk yield were higher under N2 (75% RDN + 25% FYM) treatment, which was statistically at par with N3 (75% RDN + 25% neem cake) treatment across both years and pooled data. The variations in seed cotton yield were linked to nutrient availability, as indicated by positive correlation between yield and available nitrogen status. Treatments incorporating organic sources resulted in significantly higher yields compared to those relying solely on inorganic fertilizers. This increase can be attributed to gradual nutrient release through mineralization, improved microbial activity, and enhanced nutrient availability from organic matter decomposition. The combination of organic and inorganic fertilizers ensured a steady nutrient supply, aligning with crop demand, which contributed to better root development, dry matter production, and efficient nutrient translocation for improved seed formation. These findings are supported by previous research conducted by Meena *et al*. (2019), Parmar *et al*. (2019), Paslawar *et al*. (2019), Rakhonde *et al*. (2022) and Muthu & Rao (2023).

**Effect of sulphur on growth and yield and yield attributes**

 Application of sulphur had no significant effect on plant population (Table1) at 15 DAS and at harvest; and seed index (Table 4) during 2022-23, 2023-24, and pooled analysis, while sulphur had a significant effect on growth parameters such as plant height (Table 1) at 90 DAS (during 2023–24 and pooled basis) and at harvest, as well as monopodial (Table 2) and sympodial (Table 3) branches/plant at different growth stages. The influence of sulphur on yield attributes and overall cotton yield (Table 4) was also significant, with higher values recorded under S3 treatment (40 kg S/ha), which was statistically at par with S2 (20 kg S/ha) treatment across individual years and pooled data. The improvement in growth and yield parameters with sulphur application could be attributed to enhanced photosynthetic capacity, allowing better boll formation by enabling plants to capture more solar radiation. Additionally, sulphur supplementation in sulphur-deficient soils promoted increased plant height, sympodial branching, and boll formation, ultimately leading to higher seed cotton yield (Parlawar *et al*., 2018; Sankat *et al*., 2023). The enhanced availability of sulphur-containing amino acids, which are essential for protein synthesis and help to reduce boll and square shedding, further contributed to yield improvement. These findings aligned with research of Gobi *et al.* (2012).

**Interaction effect**

Data presented in Tables 5 clearly indicated that an interaction effect of nitrogen and sulphur treatments was significant for seed cotton yield during both years and in pooled results. Higher seed cotton yield (2688, 2748, and 2718 kg/ha) was recorded under the treatment combination N2S3 (75% RDN + 25% FYM + 40 kg S/ha), which were statistically at par with N3S3 (75% RDN + 25% neem cake + 40 kg S/ha) and N2S2 (75% RDN + 25% FYM + 20 kg S/ha) treatment combination across all years and pooled data.

The data presented in Tables 1, 2, and 3 indicated that interaction effect of nitrogen and sulphur treatments significantly influenced seed cotton yield during both years and in pooled results. Higher seed cotton yield (2688, 2748, and 2718 kg/ha) was recorded under treatment combination N2S3 (75% RDN + 25% FYM + 40 kg S/ha), which was statistically at par with N3S3 (75% RDN + 25% neem cake + 40 kg S/ha) and N2S2 (75% RDN + 25% FYM + 20 kg S/ha) treatment combinations across all years and pooled data. Among different nitrogen and sulphur management, with 75% RDN + 25% FYM + 40 kg S/ha (N₂S₃) fetched maximum net return of ₹93,773/ha with BCR 2.35 followed by N₂S₂ (75% RDN + 25% FYM with 20 kg S/ha) net return of ₹91,024/ha with BCR 2.33 and N3S3 (75% RDN + 25 % through neem cake + 30 kg S/ha) net return of ₹80469/ha with BCR 2.00.

**CONCLUSION**

 Based on the findings of a two-year experiment, cotton could be fertilized with 25% of RDN through FYM as a basal application, while the remaining 75% RDN should be supplied in split at 30, 60 and 90 DAS through chemical fertilizers. Additionally, applying 20 kg S/ha as a basal dose can be recommended to achieve higher seed cotton yield and higher net realization and BCR ratio.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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**Table 1: Response of nitrogen and sulphur on plant population and plant height of cotton**

|  |  |  |
| --- | --- | --- |
| **Tret.** | **Plant population/net plot** | **Plant height (cm)** |
| **15 DAS** | **Harvest** | **30 DAS** | **60 DAS** | **90 DAS** | **Harvest** |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Nitrogen (N)** |
| **N1** | 85.00 | 84.78 | 84.89 | 83.56 | 83.56 | 83.56 | 29.49 | 29.00 | 29.25 | 89.83 | 88.66 | 89.25 | 120 | 123 | 122 | 155 | 158 | 157 |
| **N2** | 86.33 | 86.89 | 86.61 | 85.00 | 85.78 | 85.39 | 29.44 | 30.93 | 30.19 | 88.77 | 92.32 | 90.54 | 131 | 136 | 134 | 169 | 172 | 170 |
| **N3** | 86.11 | 86.33 | 86.22 | 84.78 | 85.33 | 85.06 | 29.49 | 30.34 | 29.91 | 89.12 | 91.83 | 90.47 | 128 | 132 | 130 | 164 | 167 | 166 |
| **N4** | 86.33 | 85.78 | 86.06 | 85.00 | 84.78 | 84.89 | 29.24 | 30.70 | 29.97 | 87.77 | 90.62 | 89.20 | 124 | 126 | 125 | 158 | 160 | 159 |
| **N5** | 85.56 | 86.00 | 85.78 | 83.89 | 84.56 | 84.22 | 28.36 | 30.03 | 29.19 | 86.80 | 88.52 | 87.66 | 122 | 125 | 123 | 156 | 158 | 157 |
| **S. Em. ±** | 1.04 | 1.10 | 0.76 | 1.11 | 1.05 | 0.76 | 0.93 | 1.10 | 0.72 | 2.53 | 2.85 | 1.91 | 4 | 3 | 2 | 4 | 4 | 2 |
| **C.D.at 5%** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 9 | 7 | 10 | 10 | 7 |
| **Sulphur (S)** |
| **S1** | 84.80 | 84.73 | 84.77 | 83.20 | 83.67 | 83.43 | 28.85 | 29.67 | 29.26 | 87.36 | 89.18 | 88.27 | 121 | 124 | 122 | 155 | 158 | 156 |
| **S2** | 86.40 | 86.27 | 86.33 | 85.20 | 85.13 | 85.17 | 29.09 | 30.41 | 29.75 | 88.85 | 89.74 | 89.30 | 124 | 129 | 127 | 160 | 163 | 162 |
| **S3** | 86.40 | 86.87 | 86.63 | 84.93 | 85.60 | 85.27 | 29.67 | 30.51 | 30.09 | 89.17 | 92.24 | 90.71 | 130 | 133 | 131 | 166 | 168 | 167 |
| **S. Em. ±** | 0.81 | 0.85 | 0.59 | 0.86 | 0.81 | 0.59 | 0.72 | 0.85 | 0.56 | 1.96 | 2.21 | 1.48 | 3 | 2 | 2 | 3 | 3 | 2 |
| **C.D.at 5%** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 7 | 5 | 8 | 8 | 5 |
| **N x S Int.** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Y** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **Y x N** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **Y x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **Y x N x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **C. V. %** | 3.64 | 3.84 | 3.74 | 3.93 | 3.72 | 3.82 | 9.55 | 10.93 | 10.29 | 8.59 | 9.45 | 9.04 | 9.00 | 7.49 | 8.26 | 6.64 | 6.46 | 6.55 |

**Table 2: Response of nitrogen and sulphur on number of monopodial branches/plant of cotton**

|  |  |
| --- | --- |
| **Treatment** | **Number of monopodial branches/plant** |
| **60 DAS** | **90 DAS** | **Harvest** |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Nitrogen (N)** |
| **N1** | 100% RDN | 1.24 | 1.22 | 1.23 | 1.53 | 1.56 | 1.54 | 1.73 | 1.76 | 1.74 |
| **N2** | 75% RDN + 25% through FYM | 1.29 | 1.24 | 1.27 | 1.71 | 1.73 | 1.72 | 1.91 | 1.98 | 1.94 |
| **N3** | 75% RDN + 25% through Neem cake | 1.27 | 1.22 | 1.24 | 1.62 | 1.69 | 1.66 | 1.82 | 1.91 | 1.87 |
| **N4** | 50% RDN + 25% through FYM + Bio NPK consortium | 1.22 | 1.24 | 1.23 | 1.58 | 1.60 | 1.59 | 1.78 | 1.80 | 1.79 |
| **N5** | 50% RDN + 25% through Neem cake + Bio NPK consortium | 1.20 | 1.22 | 1.21 | 1.60 | 1.58 | 1.59 | 1.80 | 1.78 | 1.79 |
|  | **S. Em. ±** | 0.03 | 0.02 | 0.02 | 0.04 | 0.03 | 0.02 | 0.04 | 0.03 | 0.02 |
|  | **C. D. at 5%** | NS | NS | NS | 0.10 | 0.09 | 0.07 | 0.10 | 0.10 | 0.07 |
| **Sulphur (S)** |
| **S1** | 0 kg S/ha | 1.23 | 1.21 | 1.22 | 1.53 | 1.53 | 1.53 | 1.73 | 1.73 | 1.73 |
| **S2** | 20 kg S/ha | 1.25 | 1.21 | 1.23 | 1.61 | 1.67 | 1.64 | 1.81 | 1.88 | 1.85 |
| **S3** | 40 kg S/ha | 1.25 | 1.27 | 1.26 | 1.68 | 1.69 | 1.69 | 1.88 | 1.92 | 1.90 |
|  | **S. Em. ±** | 0.02 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 |
|  | **C. D. at 5%** | NS | NS | NS | 0.08 | 0.07 | 0.05 | 0.08 | 0.07 | 0.05 |
|  | **N x S Interaction** | NS | NS | NS | NS | NS | NS | NS | NS | NS |
|  | **Y** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **Y x N** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **Y x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **Y x N x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **C. V. %** | 6.14 | 5.57 | 5.86 | 6.57 | 5.59 | 6.09 | 5.84 | 5.43 | 5.64 |

**Table 3: Response of nitrogen and sulphur on number of sympodial branches/plant of cotton**

|  |  |
| --- | --- |
| **Treatment** | **Number of sympodial branches/plant** |
| **60 DAS** | **90 DAS** | **Harvest** |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Nitrogen (N)** |
| **N1** | 100% RDN | 5.80 | 5.84 | 5.82 | 8.49 | 8.60 | 8.54 | 10.24 | 10.50 | 10.37 |
| **N2** | 75% RDN + 25% through FYM | 6.62 | 6.75 | 6.69 | 9.87 | 9.91 | 9.89 | 12.91 | 13.04 | 12.98 |
| **N3** | 75% RDN + 25% through Neem cake | 6.41 | 6.49 | 6.45 | 9.42 | 9.51 | 9.47 | 12.04 | 12.27 | 12.16 |
| **N4** | 50% RDN + 25% through FYM + Bio NPK consortium | 6.01 | 6.09 | 6.05 | 8.64 | 8.69 | 8.67 | 10.82 | 11.04 | 10.93 |
| **N5** | 50% RDN + 25% through Neem cake + Bio NPK consortium | 5.97 | 6.07 | 6.02 | 8.67 | 8.80 | 8.73 | 10.96 | 11.02 | 10.99 |
|  | **S. Em. ±** | 0.21 | 0.19 | 0.14 | 0.34 | 0.32 | 0.23 | 0.40 | 0.47 | 0.31 |
|  | **C. D. at 5%** | 0.60 | 0.56 | 0.40 | 0.97 | 0.93 | 0.66 | 1.17 | 1.35 | 0.87 |
| **Sulphur (S)** |
| **S1** | 0 kg S/ha | 5.73 | 5.80 | 5.76 | 8.52 | 8.61 | 8.57 | 10.32 | 10.48 | 10.40 |
| **S2** | 20 kg S/ha | 6.26 | 6.30 | 6.28 | 9.07 | 9.17 | 9.12 | 11.63 | 11.87 | 11.75 |
| **S3** | 40 kg S/ha | 6.50 | 6.64 | 6.57 | 9.47 | 9.52 | 9.49 | 12.24 | 12.37 | 12.31 |
|  | **S. Em. ±** | 0.16 | 0.15 | 0.11 | 0.26 | 0.25 | 0.18 | 0.31 | 0.36 | 0.24 |
|  | **C. D. at 5%** | 0.46 | 0.44 | 0.31 | 0.75 | 0.72 | 0.51 | 0.90 | 1.05 | 0.68 |
|  | **N x S Interaction** | NS | NS | NS | NS | NS | NS | NS | NS | NS |
|  | **Y** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **Y x N** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **Y x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **Y x N x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS |
|  | **C. V. %** | 10.05 | 9.36 | 9.71 | 11.16 | 10.62 | 10.89 | 10.59 | 12.09 | 11.38 |

**Table 4: Response of nitrogen and sulphur on yield and number of bolls/plant of cotton**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Yield (kg/ha)** | **Number of bolls/plant** | **Seed index (g)** |
| **Seed cotton**  | **Stalk**  |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Nitrogen (N)** |
| **N1** | 1960 | 2010 | 1985 | 5188 | 5377 | 5283 | 19.43 | 18.61 | 19.02 | 8.12 | 8.16 | 8.14 |
| **N2** | 2379 | 2462 | 2420 | 6026 | 6137 | 6082 | 23.09 | 23.31 | 23.20 | 8.21 | 8.34 | 8.28 |
| **N3** | 2239 | 2347 | 2293 | 5805 | 6025 | 5915 | 22.34 | 22.70 | 22.52 | 8.15 | 8.23 | 8.19 |
| **N4** | 2072 | 2199 | 2136 | 5427 | 5519 | 5473 | 20.30 | 20.28 | 20.29 | 8.20 | 8.22 | 8.21 |
| **N5** | 2017 | 2141 | 2079 | 5383 | 5538 | 5460 | 19.94 | 20.40 | 20.17 | 8.21 | 8.17 | 8.19 |
| **S. Em. ±** | 83 | 77 | 56 | 186 | 169 | 126 | 0.73 | 0.88 | 0.57 | 0.22 | 0.23 | 0.16 |
| **C.D.at 5%** | 240 | 222 | 160 | 538 | 490 | 356 | 2.12 | 2.55 | 1.62 | NS | NS | NS |
| **Sulphur (S)** |
| **S1** | 1910 | 1984 | 1947 | 5045 | 5161 | 5103 | 18.77 | 19.06 | 18.91 | 8.06 | 8.15 | 8.11 |
| **S2** | 2188 | 2307 | 2248 | 5692 | 5877 | 5785 | 21.49 | 21.75 | 21.62 | 8.18 | 8.22 | 8.20 |
| **S3** | 2302 | 2404 | 2353 | 5960 | 6119 | 6040 | 22.80 | 22.37 | 22.58 | 8.30 | 8.30 | 8.30 |
| **S. Em. ±** | 64 | 59 | 44 | 144 | 131 | 97 | 0.57 | 0.68 | 0.44 | 0.17 | 0.18 | 0.12 |
| **C.D.at 5%** | 186 | 172 | 124 | 417 | 379 | 276 | 1.65 | 1.98 | 1.26 | NS | NS | NS |
| **N x S Int.** | Sig | Sig | Sig. | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Y** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **Y x N** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **Y x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **Y x N x S** | --- | --- | NS | --- | --- | NS | --- | --- | NS | --- | --- | NS |
| **C. V. %** | 11.63 | 10.30 | 10.96 | 10.02 | 8.87 | 9.45 | 10.46 | 12.55 | 11.56 | 8.09 | 8.28 | 8.19 |

**Table 5 Economics of nitrogen and sulphur on seed cotton yield**

|  |  |  |
| --- | --- | --- |
| **Tre. combination** | **Seed cotton yield (kg/ha)** | **Average of two years** |
| **2022-23** | **2023-24** | **Pooled** | **Gross realization (₹)** | **Total cost of production (₹)** | **Net realization (₹)** | **BCR** |
| N1S1 | 1941 | 1959 | 1950 | 116987 | 50902 | 66085 | 2.30 |
| N1S2 | 2055 | 1959 | 2007 | 120423 | 51680 | 68743 | 2.33 |
| N1S3 | 1883 | 2113 | 1998 | 119880 | 52458 | 67422 | 2.29 |
| N2S1 | 1868 | 1899 | 1883 | 113009 | 67767 | 45242 | 1.67 |
| N2S2 | 2580 | 2739 | 2659 | 159569 | 68545 | 91024 | 2.33 |
| N2S3 | 2688 | 2748 | 2718 | 163095 | 69322 | 93773 | 2.35 |
| N3S1 | 1877 | 1986 | 1932 | 115902 | 79263 | 36640 | 1.46 |
| N3S2 | 2173 | 2345 | 2259 | 135521 | 80040 | 55480 | 1.69 |
| N3S3 | 2667 | 2709 | 2688 | 161287 | 80818 | 80469 | 2.00 |
| N4S1 | 1917 | 2070 | 1993 | 119609 | 67384 | 52225 | 1.78 |
| N4S2 | 2149 | 2290 | 2220 | 133170 | 68162 | 65008 | 1.95 |
| N4S3 | 2152 | 2236 | 2194 | 131633 | 68940 | 62693 | 1.91 |
| N5S1 | 1947 | 2004 | 1975 | 118524 | 78880 | 39644 | 1.50 |
| N5S2 | 1983 | 2203 | 2093 | 125576 | 79658 | 45918 | 1.58 |
| N5S3 | 2122 | 2215 | 2168 | 130096 | 80436 | 49661 | 1.62 |