**Influence of nitrogen and sulphur on yield, quality and nutrients content and uptake of *kharif* cotton**

**Abstract:**

 Seed cotton yield, as well as nitrogen and sulfur uptake by seed and stalk, were higher under due to application of 75% RDN + 25% through FYM and were statistically on par with application of 75% RDN + 25% through neem cake across both years and in pooled data.The effect of sulfur on seed cotton yield, oil content, and N and S uptake by seed and stalk was significant, higher values observed under application of 40 kg S/ha, which was statistically similar to application of 20 kg S/ha treatment in both individual years and pooled analysis.A significant interaction effect of nitrogen and sulfur was observed on seed cotton yield in both years and pooled data, as well as on N and S uptake by seed in pooled results. Higher values of seed cotton yield were recorded under application of treatment combination 75% RDN + 25% through FYM + 40 kg S/ha, which was statistically at par with application of treatment combination 75% RDN + 25% through neem cake + 40 kg S/ha and treatment combination of 75% RDN + 25% through FYM + 20 kg S/ha across all years and pooled results.

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

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**INTRODUCTION**

 Cotton (Gossypium hirsutum L.) is a globally significant natural fiber crop, laying a crucial role in agriculture, industry, and economy, particularly in India (Constable & Bange, 2015). India has been a leading producer of cotton and fine cotton fabrics for over 5,000 years, dating back to the Indus Valley Civilization. Until the late 18th century, India was the world's primary source of cotton (DCD, 2017). Cotton belongs to the Malvaceae family under the Gossypium genus, which consists of about 50 species found in tropical and subtropical arid to semi-arid regions (Wendel &Cronn, 2003). Uniquely, India is only the country cultivating all four majors cultivated Gossypium species: G. arboreum, G. herbaceum (Asian cotton), G. barbadense (Egyptian cotton), and G. hirsutum (American upland cotton), along with hybrid varieties. Among these, tetraploid species G. hirsutum and G. barbadense are widely cultivated, with G. hirsutum accounting for nearly 95% of the world's total cotton production, which stands at 118 million bales (Lee & Fang, 2015).

 Nitrogen, phosphorus, and potassium are essential primary nutrients that significantly enhance agricultural crop production. Among these, nitrogen is particularly crucial, as it is a decisive and often expensive input. It has the most immediate and pronounced impact on plant growth, playing a vital role in chlorophyll synthesis, protein formation, and overall crop development.

 Sulphur deficiency has become increasingly prevalent in many countries due to the adoption of high-yielding crop varieties, which extract substantial amounts of sulphur from the soil. This issue is further exacerbated by the reduced use of sulphur-containing fertilizers, leading to lower sulphur emissions and availability.

**MATERIAL AND METHOD**

During summer season of 2022–2023, a field experiment was carried out in plot No. 17–A at Regional Research Station, Anand Agricultural University, Anand (Gujarat), to investigate the 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. It was characterized by low organic carbon and available nitrogen, while available P₂O₅, K₂O, and sulphur were at medium levels. GTHV 13/28 was grown to investigate the effects of treatments 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 comprised 15 treatment combinations, replicated three times. Nitrogen was supplied using by urea in opened furrows. Soil was treated with bentonite sulfur as source of sulphur was added to the soil as part of treatment. Plucking cotton from border row plants were harvested first and all of the seed cotton from each net plot were then gathered, weighed and recorded. Total seed cotton yield, which was then converted in to kg/ha, was calculated by adding seed cotton yield data from two plucking. cotton was sown on 22 June, 2022 and 27 June, 2023.

**RESULT AND DISCUSSION**

**Effect of nitrogen and sulphur on yield and quality parameters of cotton**

 Data presented in Table 1 indicated that nitrogen application did not significantly affect oil content and ginning percentage. However, nitrogen had a significant impact on seed cotton yield, with higher yields recorded under N2 treatment (75% RDN + 25% FYM), which was statistically on par with N3 treatment (75% RDN + 25% through neem cake) across both years and in pooled data. Treatments that integrated nitrogen from organic sources resulted in significantly higher seed cotton yields compared to those receiving only inorganic fertilizers. The yield increased with FYM and neem cake application can be attributed to their role as reservoirs of macro- and micronutrients, which are gradually released through mineralization. Additionally, decomposition of organic matter produces organic acids that enhance the release of native soil nutrients, improving their availability to plants through microbial activity. The combined use of organic and inorganic fertilizers contributed to higher seed cotton yield compared to inorganic fertilizers alone, likely due to a more balanced and sustained nutrient supply aligned with crop demand. Cotton’s well-developed root system enables efficient nutrient uptake, supporting dry matter production and translocation of photosynthates to reproductive structures for better seed development. These findings align with research by Meena *et al*. (2019), Parmar *et al.* (2019), Paslawar *et al*. (2019), Rakhonde *et al*. (2022), and Muthu & Rao (2023).Data presented in Table 1 revealed that seed cotton yield and oil content were significantly higher under S3 treatment (40 kg S/ha), which was statistically on par with S2 (20 kg S/ha) across both years and in pooled data. However, sulfur application did not significantly affect ginning percentage in either year or in the pooled analysis.

**Effect of nitrogen and sulphur on nutrients content and uptake**

 Data presented in Table 2 revealed that effect of nitrogen on N and S contents in seed and stalk of cotton was non-significant during 2022-23, 2023-24, and in pooled analysis. However, among different nitrogen treatments applied to kharif cotton, N2 treatment (75% RDN + 25% though FYM) resulted in significantly higher N and S uptake by seed and stalk across both years and in pooled results. This treatment was statistically on par with N3 (75% RDN + 25% through neem cake) treatment across all years and pooled data. Regarding sulfur application, N content in seed and S content in both seed and stalk (Table 2) were significantly higher with 40 kg S/ha (S3) during 2022-23, 2023-24, and in pooled results, remaining statistically on at par with 20 kg S/ha (S2). However, sulfur levels did not significantly affect N content in stalk across both years and pooled analysis. Additionally, sulfur application at 40 kg S/ha (S3) led to significantly higher N and S uptake by seed and stalk, which was statistically at par with 20 kg S/ha (S2).

**INTERACTION EFFECT**

 Data in Table 4 indicated that interaction effect of nitrogen and sulfur treatments was significant for seed cotton yield in both years and in pooled results. Higher seed cotton yield was recorded under N2S3 treatment combination (75% RDN + 25% through FYM + 40 kg S/ha), which was statistically on at par with N3S3 (75% RDN + 25% through neem cake + 40 kg S/ha) and N2S2 (75% RDN + 25% through FYM + 20 kg S/ha) across all years and pooled data. An improvement in yield might be attributed to increased availability of sulfur-containing amino acids, essential for protein synthesis, which might help to prevent boll and square shedding. These findings are consistent with those of Gobi *et al*. (2012). Table 4 also showed that interaction effect of nitrogen and sulfur treatments significantly influenced N and S uptake by cotton seed on a pooled basis. Higher N uptake and S uptake were recorded under N2S3 treatment combination (75% RDN + 25% through FYM + 40 kg S/ha), which was statistically on par with N2S2 (75% RDN + 25% through FYM + 20 kg S/ha).However, an interaction effect of nitrogen and sulfur was found to be non-significant for oil content and ginning percentage (Table 1), as well as for N and S content in seed and stalk, N uptake by cotton seed (2022-23 and 2023-24), N uptake by the stalk, and S uptake by cotton seed and stalk (Table 3) during both individual years and in pooled analysis.

**Conclusion**

 Based on findings of a two-year experiment, for higher yield, higher protein content, better nutrient utilization, it can be recommended that 25% of recommended dose of nitrogen should be supplied through FYM as a basal application, while remaining 75% should be applied through chemical fertilizers. additionally, applying 20 kg S/ha as a basal dose.

**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 seed cotton and quality parameters of cotton**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatment** | **Seed cotton yield (kg/ha)** | **Stalk yield (kg/ha)** | **Oil content** | **Ginning percentage**  |
| **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 | 17.74 | 17.67 | 17.71 | 33.25 | 33.05 | 33.15 |
| **N2** | 2379 | 2462 | 2420 | 6026 | 6137 | 6082 | 17.95 | 18.06 | 18.01 | 33.08 | 33.44 | 33.26 |
| **N3** | 2239 | 2347 | 2293 | 5805 | 6025 | 5915 | 18.02 | 17.97 | 17.99 | 33.13 | 32.54 | 32.84 |
| **N4** | 2072 | 2199 | 2136 | 5427 | 5519 | 5473 | 17.76 | 17.92 | 17.84 | 32.99 | 32.95 | 32.97 |
| **N5** | 2017 | 2141 | 2079 | 5383 | 5538 | 5460 | 17.90 | 18.17 | 18.03 | 32.60 | 32.89 | 32.74 |
| **S. Em. ±** | 83 | 77 | 56 | 186 | 169 | 126 | 0.22 | 0.21 | 0.15 | 0.85 | 0.88 | 0.61 |
| **C.D.at 5%** | 240 | 222 | 160 | 538 | 490 | 356 | NS | NS | NS | NS | NS | NS |
| **Sulphur (S)** |
| **S1** | 1910 | 1984 | 1947 | 5045 | 5161 | 5103 | 17.31 | 17.42 | 17.36 | 33.23 | 32.97 | 33.10 |
| **S2** | 2188 | 2307 | 2248 | 5692 | 5877 | 5785 | 18.04 | 18.06 | 18.05 | 33.07 | 33.04 | 33.06 |
| **S3** | 2302 | 2404 | 2353 | 5960 | 6119 | 6040 | 18.26 | 18.39 | 18.33 | 32.73 | 32.91 | 32.82 |
| **S. Em. ±** | 64 | 59 | 44 | 144 | 131 | 97 | 0.17 | 0.16 | 0.12 | 0.66 | 0.68 | 0.47 |
| **C.D.at 5%** | 186 | 172 | 124 | 417 | 379 | 276 | 0.49 | 0.46 | 0.33 | 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 | 3.63 | 3.44 | 3.54 | 7.71 | 8.04 | 7.88 |

**Table 2: Response of nitrogen and sulphur content in cotton seed and stalk of cotton**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **N content (%)**  | **S content (%)**  |
| **Seed**  | **Stalk**  | **Seed**  | **Stalk** |
| **2022-23** | **2022-23** | **2022-23** | **2022-23** | **2022-23** | **2022-23** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Nitrogen (N)** |  |  |  |  |  |  |  |  |  |  |
| **N1** | 100% RDN | 1.81 | 1.81 | 1.81 | 0.681 | 0.687 | 0.684 | 0.434 | 0.444 | 0.439 | 0.127 | 0.133 | 0.130 |
| **N2** | 75% RDN + 25% through FYM | 1.84 | 1.86 | 1.85 | 0.712 | 0.709 | 0.711 | 0.469 | 0.478 | 0.474 | 0.134 | 0.139 | 0.136 |
| **N3** | 75% RDN + 25% through Neem cake | 1.84 | 1.83 | 1.84 | 0.689 | 0.686 | 0.687 | 0.477 | 0.469 | 0.473 | 0.134 | 0.132 | 0.133 |
| **N4** | 50% RDN + 25% through FYM + Bio NPK consortium | 1.78 | 1.80 | 1.79 | 0.682 | 0.690 | 0.686 | 0.452 | 0.467 | 0.460 | 0.134 | 0.138 | 0.136 |
| **N5** | 50% RDN + 25% through Neem cake + Bio NPK consortium | 1.77 | 1.79 | 1.78 | 0.666 | 0.666 | 0.666 | 0.480 | 0.457 | 0.469 | 0.133 | 0.134 | 0.133 |
|  | **S. Em. ±** | 0.04 | 0.04 | 0.03 | 0.018 | 0.017 | 0.012 | 0.014 | 0.015 | 0.010 | 0.002 | 0.003 | 0.002 |
|  | **C. D. at 5%** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Sulphur (S)** |  |  |  |  |   |   |  |   |   |  |   |   |
| **S1** | 0 kg S/ha | 1.74 | 1.75 | 1.75 | 0.665 | 0.674 | 0.670 | 0.428 | 0.425 | 0.427 | 0.106 | 0.110 | 0.108 |
| **S2** | 20 kg S/ha | 1.82 | 1.85 | 1.83 | 0.684 | 0.689 | 0.687 | 0.467 | 0.480 | 0.474 | 0.137 | 0.139 | 0.138 |
| **S3** | 40 kg S/ha | 1.86 | 1.86 | 1.86 | 0.709 | 0.699 | 0.704 | 0.492 | 0.485 | 0.488 | 0.154 | 0.156 | 0.155 |
|  | **S. Em. ±** | 0.03 | 0.03 | 0.02 | 0.014 | 0.013 | 0.010 | 0.011 | 0.012 | 0.008 | 0.002 | 0.002 | 0.001 |
|  | **C. D. at 5%** | 0.09 | 0.08 | 0.06 | NS | NS | NS | 0.031 | 0.034 | 0.023 | 0.005 | 0.007 | 0.004 |
|  | **N x S Interaction** | NS | NS | NS | 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. %** | 6.42 | 6.21 | 6.31 | 8.00 | 7.35 | 7.68 | 9.07 | 9.89 | 9.49 | 5.54 | 6.49 | 6.05 |

**Table 3: Response of nitrogen and sulphur uptake by cotton seed and stalk of cotton**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **N uptake (kg/ha)**  | **S uptake (kg/ha)**  |
| **Seed**  | **Stalk** | **Seed**  | **Stalk** |
| **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Nitrogen (N)** |  |  |  |  |  |  |  |  |  |  |
| **N1** | 100% RDN | 35.20 | 36.42 | 35.81 | 35.47 | 36.93 | 36.20 | 8.47 | 8.96 | 8.71 | 6.64 | 7.21 | 6.92 |
| **N2** | 75% RDN + 25% through FYM | 44.08 | 46.10 | 45.09 | 43.04 | 43.62 | 43.33 | 11.27 | 11.85 | 11.56 | 8.19 | 8.60 | 8.39 |
| **N3** | 75% RDN + 25% through Neem cake | 41.19 | 43.26 | 42.23 | 40.02 | 41.33 | 40.68 | 10.71 | 11.10 | 10.90 | 7.87 | 8.04 | 7.96 |
| **N4** | 50% RDN + 25% through FYM + Bio NPK consortium | 37.03 | 39.66 | 38.34 | 37.07 | 38.02 | 37.54 | 9.39 | 10.27 | 9.83 | 7.33 | 7.67 | 7.50 |
| **N5** | 50% RDN + 25% through Neem cake + Bio NPK consortium | 35.75 | 38.38 | 37.06 | 35.80 | 36.90 | 36.35 | 9.65 | 9.84 | 9.75 | 7.20 | 7.46 | 7.33 |
|  | **S. Em. ±** | 1.72 | 1.71 | 1.21 | 1.51 | 1.40 | 1.03 | 0.44 | 0.50 | 0.33 | 0.29 | 0.29 | 0.21 |
|  | **C. D. at 5%** | 4.97 | 4.96 | 3.43 | 4.38 | 4.06 | 2.92 | 1.27 | 1.44 | 0.94 | 0.84 | 0.84 | 0.58 |
| **Sulphur (S)** |  |  |  |  |  |  |  |  |  |  |  |  |
| **S1** | 0 kg S/ha | 33.23 | 34.75 | 33.99 | 33.52 | 34.88 | 34.20 | 8.13 | 8.45 | 8.29 | 5.37 | 5.67 | 5.52 |
| **S2** | 20 kg S/ha | 39.77 | 42.72 | 41.24 | 38.92 | 40.50 | 39.71 | 10.20 | 11.14 | 10.67 | 7.77 | 8.19 | 7.98 |
| **S3** | 40 kg S/ha | 42.95 | 44.82 | 43.89 | 42.40 | 42.70 | 42.55 | 11.36 | 11.63 | 11.50 | 9.19 | 9.53 | 9.36 |
|  | **S. Em. ±** | 1.33 | 1.33 | 0.94 | 1.17 | 1.09 | 0.80 | 0.34 | 0.39 | 0.26 | 0.22 | 0.23 | 0.16 |
|  | **C. D. at 5%** | 3.85 | 3.84 | 2.66 | 3.40 | 3.15 | 2.26 | 0.99 | 1.12 | 0.73 | 0.65 | 0.65 | 0.45 |
|  | **N x S Interaction** | NS | NS | **Sig**. | NS | NS | NS | NS | NS | **Sig.** | 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. %** | 13.32 | 12.59 | 12.95 | 11.86 | 10.69 | 11.27 | 13.32 | 14.37 | 13.89 | 11.68 | 11.21 | 11.44 |

**Table 4: Interaction effect of nitrogen and sulphur on yield, nutrient uptake and BCR ratio of cotton**

|  |  |  |  |
| --- | --- | --- | --- |
| **T.****combination** | **Seed cotton yield (kg/ha)** | **Pooled (uptake kg/ha)** | **Average of two years** |
| **2022-23** | **2023-24** | **Pooled** | **N**  | **S**  | **Gross realization (₹)** | **Total cost of production (₹)** | **Net realization (₹)** | **BCR** |
| N1S1 | 1941 | 1959 | 1950 | 34.13 | 7.70 | 116987 | 50902 | 66085 | 2.30 |
| N1S2 | 2055 | 1959 | 2007 | 36.23 | 8.92 | 120423 | 51680 | 68743 | 2.33 |
| N1S3 | 1883 | 2113 | 1998 | 37.07 | 9.51 | 119880 | 52458 | 67422 | 2.29 |
| N2S1 | 1868 | 1899 | 1883 | 33.08 | 8.43 | 113009 | 67767 | 45242 | 1.67 |
| N2S2 | 2580 | 2739 | 2659 | 49.16 | 12.92 | 159569 | 68545 | 91024 | 2.33 |
| N2S3 | 2688 | 2748 | 2718 | 53.04 | 13.33 | 163095 | 69322 | 93773 | 2.35 |
| N3S1 | 1877 | 1986 | 1932 | 34.46 | 8.45 | 115902 | 79263 | 36640 | 1.46 |
| N3S2 | 2173 | 2345 | 2259 | 42.11 | 10.99 | 135521 | 80040 | 55480 | 1.69 |
| N3S3 | 2667 | 2709 | 2688 | 50.11 | 13.27 | 161287 | 80818 | 80469 | 2.00 |
| N4S1 | 1917 | 2070 | 1993 | 34.39 | 8.35 | 119609 | 67384 | 52225 | 1.78 |
| N4S2 | 2149 | 2290 | 2220 | 40.87 | 10.55 | 133170 | 68162 | 65008 | 1.95 |
| N4S3 | 2152 | 2236 | 2194 | 39.77 | 10.6 | 131633 | 68940 | 62693 | 1.91 |
| N5S1 | 1947 | 2004 | 1975 | 33.9 | 8.5 | 118524 | 78880 | 39644 | 1.50 |
| N5S2 | 1983 | 2203 | 2093 | 37.84 | 9.97 | 125576 | 79658 | 45918 | 1.58 |
| N5S3 | 2122 | 2215 | 2168 | 39.45 | 10.77 | 130096 | 80436 | 49661 | 1.62 |