**Original Research Article**

**Effect of Sources and Levels of Sulphur on Growth and Economics of Toria (*Brassica campestris* var*. toria*)**

**Abstract**

A field experiment was carried out during the *rabi* season of 2024-25 at the Crop Research Farm, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.), India, to evaluate how different sources and levels of sulphur affect the growth and yield of the toria crop. The study included three sulphur sources—Single Super Phosphate, Gypsum, and Ammonium Sulphate—applied at three different levels: 30, 45, and 60 kg S/ha, along with a control (no sulphur). Treatments were laid out in a factorial design and replicated three times. The results showed that the application of Ammonium Sulphate at 60 kg S/ha delivered the most promising outcomes. This treatment recorded the tallest plants (112.25 cm), highest dry weight (19.33 g), most branches per plant (8.47), highest crop growth rate (17.4 g/m²/day), maximum siliquae per plant (155.73), more seeds per siliqua (15.53), and the highest seed (1.18 t/ha) and stover yields (2.37 t/ha). Economically, this treatment also outperformed all others, with the highest gross return (₹74,712/ha), net return (₹45,692/ha), and a benefit-cost (B:C) ratio of 1.57, indicating strong profitability alongside improved crop performance.

***Keywords:*** Sulphur, Sources, SSP, Ammonium sulphate, Gypsum, Toria.

**Introduction**

Rapeseed (*Brassica* *campestris* var. *toria*), commonly known in India as raya, rai, or lahi, is a key oilseed crop from the Brassica family. It ranks as India’s second most important edible oilseed after groundnut, contributing nearly 30% of the country’s total oilseed production. Within the rapeseed-mustard group—an essential segment of India’s edible oil sector—rapeseed-mustard accounts for around 85% of production in this group and roughly 26.1% of total oilseed output **(Meena *et al*., 2011).** Globally, rapeseed and mustard crops are cultivated across 53 countries, spanning 24.2 million hectares over six continents. India alone contributes 28.3% of the global area and 19.8% of total production.

Nutritionally, rapeseed is rich in essential minerals such as calcium, manganese, copper, iron, selenium, and zinc, along with vitamins A, B, and C, and protein. A 100-gram serving of mustard seeds contains approximately 508 kcal, 12.2 g of dietary fiber, 26.08 g of fat, 26.08 g of protein, and 28.09 g of carbohydrates.

Sulphur plays a vital role in the growth and productivity of oilseed crops like toria. It is especially important for synthesizing sulfur-containing amino acids like cystine (27%), cysteine (26%), and methionine (21%), which are crucial for protein formation, oil synthesis, and overall plant development. Sulphur also contributes to chlorophyll formation, essential for photosynthesis, as well as the production of glucosides and glucosinolates—compounds that influence both plant health and the distinct flavor of mustard and rapeseed oils **(Kumar and Trivedi, 2012).** Crops in the Brassica family are particularly sensitive to sulfur deficiency, often showing symptoms like cupped or curled leaves with reddish undersides. In severe cases, the deficiency can extend to stems and leaf surfaces.

With these considerations in mind, the present study**—“Effects of Sources and Levels of Sulphur on Growth Performance and Economic Return of Toria (*Brassica* *campestris* L.)”**—was conducted during the 2024–25 *rabi* season at the Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh.

**Materialsand Method**

**Experimental sites and soil**

The experiment is conducted during the *Rabi* season of 2024-25 at the Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. The experimental site is geographically located at 25°24’42” N latitude, 81°50’56” E longitude, and 98 m altitude from sea level. The site lies on the right side of the river Yamuna, opposite Prayagraj city, and is approximately 5 km away from Prayagraj-Rewa Road.

**Formulations Used for the Experiment**

The experiment was carried out using a Randomized Block Design with ten different treatments and three replications. Each replication was divided into ten equal plots, where the treatments were applied. The aim was to study the effects of various sources and levels of sulphur fertilizers.

To avoid placing the same treatments next to each other, the treatments were randomly assigned to the plots. The treatment combinations were as follows:

* **T1**: Single Super Phosphate at 30 kg/ha
* **T2**: Single Super Phosphate at 45 kg/ha
* **T3**: Single Super Phosphate at 60 kg/ha
* **T4**: Gypsum at 30 kg/ha
* **T5**: Gypsum at 45 kg/ha
* **T6**: Gypsum at 60 kg/ha
* **T7**: Ammonium Sulphate at 30 kg/ha
* **T8**: Ammonium Sulphate at 45 kg/ha
* **T9**: Ammonium Sulphate at 60 kg/ha
* **T10**: Control (no sulphur fertilizer applied)

**Physiological Parameters determination**

The experiment is conducted to study the physiological growth parameters of the crop during its growth stages. At 15 DAS (Days After Sowing), 5 plants were randomly tagged from each plot to observe the growth pattern. The plant height is measured using a scale at 20 DAS and continued at 20-day intervals throughout the crop growth period. To record the dry weight, 5 plants, excluding the tagged ones, were collected from each plot at 20-day intervals. These plants were first dried in open air and then placed in a hot air oven for 24 hours to ensure complete drying. After drying, the dry weight of the samples is measured using a weighing balance. The collected dry weight data were then utilized to calculate the Crop Growth Rate **(CGR)** and Relative Growth Rate **(RGR)** using a standard formula. This process helped in understanding the growth performance and biomass accumulation of the crop under the given experimental conditions.

**CGR= (W2−W1)/​ {S(t2−t1)}**

Where:

* **W1** = Dry weight per unit area at time **t1** (initial time)
* **W2** = Dry weight per unit area at time **t2** (final time)
* **S** = Ground area (m²)
* **t2 - t1** = Time interval between two successive samplings (days)

Same way the Relative Growth Rate (RGR) also been calculated by using the formula –

**RGR (g/g/day) = logeW2–logeW1/ (t2– t1)**

Where,

 **Loge W1** = Natural log of the initial dry weight (g) of the plants at time **t1**

 **Loge W2** = Natural log of the dry weight (g) of the plants after a certain time interval **t2**

 **t1** = Initial time of data collection (days)

 **t2** = Time after a certain interval (days)

**Statistical Analysis**

The collected data were analyzed using MS Excel software, and the results were expressed as arithmetic mean values with standard deviation (±SD). The Analysis of Variance (ANOVA) method of ***Gomez and Gomez* (1984)** is used to determine the significant differences between treatments. The significance level is set at P<0.05, meaning the differences among treatments were considered statistically significant if the P-value is less than 0.05.

**Economic Analysis**

The economic analysis is conducted to evaluate the cost-effectiveness of different treatments in Toria cultivation. The following economic parameters were considered:

* **Cost of Cultivation:** It refers to the total expenditure incurred during the cultivation process, including the cost of seeds, fertilizers, pesticides, labor, irrigation, machinery, and land rent. This helps in understanding the total investment required for crop production.
* **Gross Return:** It represents the total income generated from the sale of Toria seeds without deducting any production costs.
* **Net Return:** The profit earned after deducting the total cost of cultivation from the gross return, indicating the actual income from Toria production.
* **Benefit-Cost (B:C) Ratio:** It is calculated by dividing the gross return by the total cost of cultivation. B:C ratio greater than 1 indicates a profitable investment, whereas a ratio less than 1 suggests a loss.

This analysis provided a clear understanding of the profitability and economic feasibility of different treatments in Toria cultivation.

**RESULT AND DISCUSSION**

**Plant height**

At 80 DAS, the significantly higher plant height (112.25 cm) is observed in treatment-9 (Ammonium sulphate @ 60 kg/ha). It play vital role of **sulphur nutrition**, particularly when supplied via **ammonium sulphate**, in driving vegetative development. Sulphur is essential for the synthesis of amino acids (like cysteine and methionine), vitamins, and enzymes that directly influence physiological and metabolic processes involved in growth.Higher availability of sulphur likely facilitated better nitrogen metabolism as well, considering that ammonium sulphate supplies both **N** and **S.** The synergy between these two nutrients promotes **protein synthesis** and **chlorophyll development,** enhancing the plant's photosynthetic efficiency and energy availability, which are key contributors to plant height.

Moreover, the role of sulphur in maintaining cell turgor pressure supports **cell expansion**, a crucial factor for elongation of internodes and overall vertical growth. This growth advantage may translate into better light interception and competitive ability of the crop, especially under dense planting or field stress conditions. This could be attributed to enough nutrients, which aid in rapid vegetative growth of plants and, as a result, enhance plant height through cell elongation, cell division, photosynthesis, and plant cell turbidity **Tripathi *et al*. (2011); Ray *et al*. (2015).**

**Plant dry weight (g/plant)**

At 80 DAS, the significantly higher plant dry weight (19.33 g) is observed in treatment-9 (Ammonium sulphate at 60 kg/ha).Sulphur contributes to the synthesis of essential amino acids and enzymes that are integral to cellular metabolism, enabling plants to assimilate and convert nutrients more efficiently into structural and functional biomass. The dual nutrient effect of **ammonium sulphate,** supplying both nitrogen and sulphur, likely created a synergistic effect, where nitrogen supported vegetative growth and sulphur facilitated more efficient use of that nitrogen. This interaction promotes **enhanced photosynthetic capacity, greater leaf area,** and **stronger root systems,** all of which are critical in supporting higher dry matter accumulation.

Increased dry weight is a direct indicator of **better resource use efficiency** and is often positively correlated with yield potential. The accumulation of more biomass reflects the plant’s ability to sustain active growth over time, even as competition for light, water, and nutrients increase as a result of increasing plant height, number of branches and leaves, and other above ground and below ground plant structures, which were the probable reason for hastening the dry matter accumulations in plant **Mallick *et al*. (2015);** **Skwierawska *et al*. (2016); Singh *et al*. (2021).**

**Branches/plant (no.)**

The significant higher number of branches (8.47) is observed in treatment-9 (Ammonium sulphate at 60kg/ha), which is significantly superior over rest of the treatments. However, treatment-3 (SSP at 60 kg/ha) and treatment-6 (Gypsum at 60kg/ha) is found to be statistically at par with treatment- 9 (Ammonium sulphate at 60kg/ha). **Sulphur plays a** crucial role **in regulating meristematic activity** and **cell division**, which are essential for the initiation and development of axillary buds. A greater number of branches enhances the plant's reproductive potential by supporting more flowering sites, which can directly impact yield components such as the number of siliquae and seeds.

While ammonium sulphate proved most effective, the similar performance of SSP and gypsum at equivalent sulphur doses suggests that **sulphur availability,** rather than the specific form, is the determining factor—provided it is efficiently absorbed. However, ammonium sulphate may offer an added advantage by supplying nitrogen alongside sulphur, potentially enhancing early vegetative vigor, which sets the stage for higher branching later in the crop cycle.

The role of sulphur in **protein synthesis,** particularly in enzymes and structural proteins, underpins its importance during both vegetative and reproductive phases. Adequate sulphur ensures that energy and nutrient assimilation are not limited, thereby supporting the physiological processes required for robust branch development **(Mohammadi *et al*., 2005; Prajapati *et al*., 2023).**

**Crop growth rate (g/m2/day)**

### At 60-80 DAS, the significantly higher crop growth rate (17.398 g/m2/day) is observed in treatment-9 (Ammonium sulphate at 60 kg/ha). However, treatment-4 (Gypsum at 30 kg/ha) and treatment-8 (Ammonium sulphate at 45 kg/ha) is found to be statistically at par with treatment-9.

The comparable performance of Treatments 4 and 8 with Treatment 9 suggests that both **gypsum** and **ammonium sulphate**, when applied at sufficient levels, can supply adequate sulphur to meet crop demands. However, the slightly higher efficiency observed with ammonium sulphate at 60 kg/ha may be attributed to its quicker solubility and dual nutrient supply (nitrogen and sulphur), making it more readily available for uptake.

Moreover, increased sulphur availability appears to have promoted robust vegetative development, which is a prerequisite for efficient source–sink relationships in plants. Enhanced canopy size and photosynthetic surface area during this phase allow for better energy capture, leading to higher dry matter accumulation.

Sulphur levels that aid in promoting and hastening the metabolic process, physiological activities, and increasing the photosynthesis process related to growth as a result of increasing plant height, number of branches and leaves, and other above ground and below ground plant structures that were the probable reason for the eventual increase in crop growth rate Mallick *et al.* (2015); Ray *et al*. (2015).

### Relative growth rate (g/g/day)

At 20-40 DAS the maximum relative crop growth rate (0.151 g/g/day) is observed in treatment-6 (Gypsum @ 60 kg S/ha). CGR and RGR are the growth indices which are calculated from the change in dry matter accumulation to study the growth of the plant within a particular time interval. Sulfur is known to enhance chlorophyll synthesis, enzyme activity, and protein formation, all of which are fundamental to photosynthetic efficiency and metabolic activity. The improved growth indices in Treatment-6 suggest that optimal sulfur availability can accelerate physiological processes that govern biomass production.

Moreover, canopy formation during this phase is crucial as it determines the extent of light capture, influencing the photosynthetic potential of the crop. A well-developed canopy contributes to a higher leaf area index (LAI), reducing soil evaporation and supporting better water use efficiency. These effects collectively enhance crop vigor, potentially translating into higher yield if sustained through later growth stages.

The findings suggest that sulfur application affects plant growth dynamics and influences canopy formation, which is crucial for optimal light interception and biomass accumulation **(Soni & Singh, 2023).**

Table 1: - Effect of sources and levels of Sulphur on Growth attributes of Toria.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatments** | **Plant height**  **(cm)**  **(At Harvest)** | **Dry Weight/plant(g)**  **(At Harvest)** | **Branches/plant**  **(no.)**  **(At harvest)** | **CGR**  **(g/m2/day)**  **60 – 80 DAS** | **RGR**  **(g/g/day)**  **20-40**  **DAS** |
| T1 | 102.73 | 17.08 | 7.47 | 16.147 | 0.139 |
| T2 | 104.60 | 16.98 | 8.00 | 15.469 | 0.129 |
| T3 | 110.89 | 18.28 | 8.27 | 15.884 | 0.126 |
| T4 | 104.19 | 17.36 | 7.33 | 16.300 | 0.128 |
| T5 | 108.97 | 17.37 | 7.80 | 15.586 | 0.138 |
| T6 | 110.31 | 17.78 | 8.27 | 15.120 | 0.139 |
| T7 | 104.83 | 17.47 | 7.80 | 16.134 | 0.122 |
| T8 | 109.78 | 18.19 | 8.07 | 16.294 | 0.140 |
| T9 | 112.25 | 19.33 | 8.47 | 17.398 | 0.151 |
| T10 | 101.08 | 16.23 | 7.27 | 15.379 | 0.131 |
| **F-Test** | **S** | **S** | **S** | **S** | **NS** |
| **SEm(+)** | 0.60 | 0.21 | 0.10 | 0.41 | 0.01 |
| **CD(p=0.05)** | 2.78 | 0.61 | 0.29 | 1.21 | - |

**Economics**

The economic analysis showed significant differences among treatments in terms of cost of cultivation, gross returns, net returns, and B:C ratio. The maximum gross return (INR 74,712.00/ha) and net return (INR 45,692.00/ha) were achieved in Treatment 9 (Ammonium sulphate @ 60kg S/ha).

Highest benefit cost ratio(1.57) is recorded in treatment 9 (Ammonium sulphate @ 60kg S/ha) as compared to other treatments. Higher B:C ratio is observed with Ammonium sulphate applied with 60kg S/ha in Toria might be due to increased economic performance of crop such as yield of seed and stover, which in turn led to higher gross returns and net returns.

**Table 2: - Economics of different treatments in Toria.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Cost of**  **Cultivation**  **(INR/ha)** | **Gross**  **Return**  **(INR/ha)** | **Net return**  **(INR/ha)** | **B:C**  **Ratio** |
| T1 | 26770.00 | 60742.00 | 33972.00 | 1.27 |
| T2 | 27770.00 | 63401.00 | 35631.00 | 1.28 |
| T3 | 28020.00 | 64553.50 | 36533.50 | 1.30 |
| T4 | 26076.50 | 60090.50 | 34014.00 | 1.30 |
| T5 | 26480.00 | 61555.00 | 35075.00 | 1.32 |
| T6 | 26883.00 | 67670.00 | 40787.00 | 1.52 |
| T7 | 27145.00 | 64968.50 | 37823.50 | 1.39 |
| T8 | 28082.50 | 67728.00 | 39645.50 | 1.41 |
| T9 | 29020.00 | 74712.00 | 45692.00 | 1.57 |
| T10 | 25270.00 | 57806.00 | 32536.00 | 1.29 |

**Conclusion**

It can be concluded that with the application of Ammonium sulphate at 60kg/ha (Treatment-9), is found the most superior treatment combination for obtaining higher seed yield (1.18 t/ha) and net returns (INR 45692.00/ha) in Toria.

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