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Impact of different levels of sulphur on growth of mustard (*Brassica juncea* L.)

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Abstract
The present investigation entitled "Impact of different levels of sulphur on growth of Mustard (*Brassica juncea* L.) was conducted at Research farm of Sardar Patel University, Balaghat (M.P.) during Kharif season of 2022-23 in Randomized Block Design (RBD) with three replications and ten treatments. The Study revealed that the characters plant height (30, 60 and 90 DAS) and no. of Branches (45 DAS), reported significant variation between different level of potash on mustard. Pooled data revealed that the maximum plant height, no. of Leaves and no. of Branches was recorded from T_6 (NPK 40:60:40 + 35 kg sulphur/ha.) followed by T_5 (NPK 40:60:40 + 30 kg sulphur/ha.) and T_7 (NPK 40:60:40 + 40 kg sulphur/ha.) whereas minimum plant height and no. of Branches was reported by T_1 Control.

Keywords: Impact, sulphur, pooled, RBD

Introduction

Rapeseed and mustard belong to family Cruciferae, which is grown in northern India comprising traditionally grown indigenous species namely Indian mustard (*Brassica juncea*), brown sarson (*Brassica compestris* var. brown Sarson), Yellow sarson (*Brassica compestris* var. yellow Sarson), Toria (*Brassica compestris* var. toria) and Taramira (*Eruca sativa*) along with nontraditional The group includes species such as Gobhi Sarson (*Brassica napus*), White Mustard (*Brassica alba*), and Ethiopian Mustard (*Brassica carinata*). This is the most important group of *Rabi* oilseed crops and contributes significantly to the country's vegetable fat economy. In India, more than 80% of the vegetable oil and fat requirements are fulfilled by seven major edible oilseed crops: Groundnut, Rapeseed and Mustard, Soybean, Sunflower, Niger, Sesamum, Safflower.

India holds a prominent position in the global oilseed landscape, accounting for approximately 22.5% of the total area under oilseeds and about 15% of global production (FAO, Yearbook 2002). Within India, oilseeds constitute the second-largest agricultural commodity after cereals, with a production of 15.4 million tonnes from an area of 22.9 million hectares. Oilseeds are a rich source of energy and nutrition, playing a vital role in combating malnutrition and supporting the caloric needs of both humans and livestock.

Over the past fifteen years, the oilseed sector in India has witnessed a remarkable transformation. From being a net importer during the 1980s, India emerged as a self-sufficient nation and even a net exporter of oilseeds in the early 1990s—a shift that has been popularly referred to as the "Yellow Revolution".

Mustard seeds are notable for their high oil content, which ranges between 37% and 49% (Bhowmik *et al*., 2014) [2]. The oil is rich in essential fatty acids, containing approximately 38-57% erucic acid and 27% oleic acid. After oil extraction, the mustard seed cake—a nutrient-rich by-product—is commonly utilized as both cattle feed and organic manure. It contains valuable nutrients, including:

- 5.1% Nitrogen (N)
- 1.8% Phosphorus pentoxide (P_2O_5)
- 1.1% Potassium oxide (K_2O)

In culinary applications, mustard seeds are widely used as a condiment, especially in the preparation of pickles, and for flavoring curries and vegetables. The extracted mustard oil is a staple cooking medium in northern India.

Agronomically, mustard is a promising Rabi (winter) crop due to its adaptability and ability to grow on residual soil moisture (Mukherjee, 2010) [3]. From a nutritional perspective, fats and oils play a critical role in the human diet by providing a dense source of energy and serving as carriers of fat-soluble vitamins. The mustard oil cake is especially valued in animal feed due to its high protein content. For a balanced human diet, an average daily intake of 55 grams of edible oil per person is considered essential.

India holds a significant position in the global edible oil industry, ranking as the fourth-largest market after the United States, China, and Brazil. According to the USDA (2018) [4], during 2016-17, India accounted for approximately: 7% of global edible oil production, 12% of global consumption, 20% of global imports. India is also one of the top three oilseed-producing countries in the world, following Canada and China. In the global context, during 2020-21, the rapeseed-mustard crop was cultivated on approximately 37.08 million hectares, with a total production of 71.62 million tonnes and an average productivity of 1,920 kg/ha (Anonymous, 2010) [8].

Mustard is the second most important edible oilseed crop in India, following groundnut. It plays a significant role in the country's oilseed economy. During the 2020-21 period, the area under rapeseed-mustard cultivation was approximately 6.87 million hectares, with a total production of 8.12 million tonnes and an average productivity of 1304 kg/ha (DRMR, 2018) [6].

In Uttar Pradesh, during the year 2020-21, the area under rapeseed-mustard cultivation was 1.03 million hectares (mha), with a production of 1.15 million tonnes (mt) and a productivity of 1,055 kg/ha. Rajasthan had the largest area (2.12 mha) and the highest production (2.45 mt), although its productivity was lower at 1,155 kg/ha. In contrast, Gujarat recorded the highest productivity at 1,363 kg/ha, despite having a smaller cultivated area of 0.22 mha and a total production of 0.30 mt. Within Uttar Pradesh, Mathura district reported the highest area, production, and productivity of rapeseed-mustard, with 0.053 mha, 0.077 mt, and 1,453 kg/ha, respectively (SEA, 2018) [7].

Yellow Sarson (*Brassica campestris* L.) is an important oilseed crop belonging to the family Cruciferae. It holds a prominent position among oilseed crops, ranking next to groundnut in importance. Currently, the total oilseed production in India is approximately 27.7 million tonnes, with yellow sarson cultivated on about 7.1 million hectares, yielding around 8.1 million tonnes. The average productivity of oilseeds in India stands at 1,000 kg/ha, while for rapeseed and yellow sarson, it is notably higher at 1,115 kg/ha. India contributes about 12-13% of the world's oilseed production. In the state of Uttar Pradesh, mustard covers an area of 0.781 million hectares, producing around 0.957 million tonnes (Anonymous, 2010) [8].

India contributes approximately 23% to the global production of yellow sarson and rapeseed. These oilseed crops hold particular importance in the states of Rajasthan and Uttar Pradesh, which together account for nearly 80% of the total cultivated area and production in the country. In Uttar Pradesh alone, mustard is cultivated over an area of 0.781 million hectares, yielding a production of 0.957 million tonnes (Hedge, 2007) [9].

Nearly 76% oilseeds area is rainfed which is often subjected to erratic monsoon. The oil content of the yellow sarson seeds ranges from 41-47% and 20-40% protein. The seed and oil are used as condiments in the preparation of pickles and for flavouring curries and vegetables. The oil cake is mostly used as a cattle feed and the leaves of young plants are used as green vegetables. The use of mustard oil for industrial purposes is rather limited on account of its high cost. Apart from this yellow mustard cake is also used as organic manure for the soil. Sulphur and boron are most vital nutrients for growth and development oil seeds. Sulphur is recognized as the fourth most important essential nutrient for plant growth, following nitrogen, phosphorus, and potassium. Key Functions of Sulphur in Plants: Amino Acid Synthesis: Essential for the formation of sulphur-containing amino acids such as cysteine and methionine. Chlorophyll Production: Plays a crucial role in chlorophyll synthesis, aiding in photosynthesis. Oil Content Enhancement: Increases oil content, especially in oilseed crops. Vitamin Synthesis: Involved in the production of vitamins such as: Vitamin B, Biotin, Thiamine. Metabolism: Supports carbohydrate, protein, and fat metabolism. Flavor Compound Formation: Crucial for the formation of flavour compounds, particularly in crops like crucifers (e.g., cabbage, mustard). Coenzyme-A Synthesis: Participates in the synthesis of coenzyme-A, which is vital for energy production and metabolism.

Sulphur is recognized as the second most essential nutrient for Brassica crops, following nitrogen. These crops have a significantly higher sulphur requirement compared to others, primarily due to the need for synthesizing thioglucosides and other related compounds, which can constitute up to 3% of the plant's dry weight. In oilseeds, sulphur plays a crucial role in boosting production. Additionally, it is vital for the synthesis of several important biochemical compounds, including:

- Vitamins: Such as Thiamine and Biotin
- Lipoid acid
- Glutathiones

Materials and Methods

A field experiment entitled "Impact of different levels of sulphur on growth of Mustard (*Brassica juncea* L.)" was conducted during rabi season of 2022-23. The details of the experimental materials used and the technique adopted during the course of investigation are given in this chapter under the following heads.

Location of experimental: Site The experimental site was selected on the merit in respect of suitability of land with uniform fertility and topography. The present investigation was laid out in at the Research Farm of Sardar Patel University, Balaghat (M.P) during rabi season 2022-2023.

Climate and Weather condition: Balaghat is situated at a latitude of 21°48′ N and a longitude of 80°11′ E, with an elevation of 288 meters above mean sea level (MSL). The region falls under the sub-tropical climatic zone, characterized by assured but variable rainfall during the kharif season, a generally cool rabi season, and a hot and dry summer.

Experimental design and treatments: The experiment was conducted in "Randomized Block Design" with ten treatment and three replications. The treatments were allotted randomly in various plots.

Name of crop: Mustard (*Brassica juncea* L.)
Variety: mNPJ113
Season: Rabi
Design: RBD (Randomized Block Design)
No. of Treatments: 10
No. of Replications: 03
Total Number of plots 30
Fertilizer dose: 60:40:40 (N: P_2O_5:K_2O)S Kg/ha
Gross Plot Size: 3.2 m×8.3 m
Net Plot Size: 2.7 m×7.3 m
Total experimental area:-32 m x 24 m (768 m)
No. of rows per plot: 5
Distance between plots: 0.5 m
Distance between replication: 1.0 m
Plant to plant distance: 0.15 m and Row to row distance:-0.3 m
Date of sowing: 09/11/2022
Seed rate: 12 kg/ha.

Treatments detail: T_1 Control, T_2 NPK 40:60:40 + 15 kg sulphur/ha, T_3 NPK 40:60:40 + 20 kg sulphur/ha, T_4 NPK 40:60:40 + 25 kg sulphur/ha, T_5 NPK 40:60:40 + 30 kg sulphur/ha, T_6 NPK 40:60:40 + 35 kg/sulphur ha, T_7 NPK 40:60:40 + 40 kg sulphur ha, T_8 NPK 40:60:40 + 45 kg sulphur/ha, T_9 NPK 40:60:40 + 50 kg sulphur/ha, T_{10} NPK 40:60:40 + 55 kg sulphur/ha.

Growth Parameters

Plant Height (cm): Plant height was recorded at 30, 60, and 90 days after sowing (DAS), measured from the base of the plant to the tip of the fully expanded leaf on the main shoot. The average height of five randomly selected plants was calculated and expressed in centimetres.

Number of branches per plant: The number of branches was counted and the average of five plants was expressed in number of branches per plant.

No. of Leaves: 30 60 DAS.

Results

1. Plant Height: The findings regarding the impact of varying sulphur levels on the height of mustered plants at 30, 60 and 90 days after sowing (DAS) are detailed in Table 1 and illustrated in Statistically significant differences in plant height were observed at all recorded stages, specifically at 30, 60, and 90 DAS, among the different combinations applied. The tallest plants measured 19.00 cm, 125.57 cm, and 167.67 cm at 30, 60, and 90 DAS, respectively, with treatment T_6 (60:40:40 NPK + 35 Kg ha-1sulphur) leading the results. Treatment T_5 (40:60:40 NPK + 30 kg ha 1sulphur) followed closely, yielding heights of 18.62 cm, 124.47 cm, and 163.83 cm at the same field. In contrast, the control group (T_1) exhibited the shortest heights of 13.33cm, 115.59 cm, and 151.27 cm at 30, 60, and 90 DAS, respectively, while the other treatments displayed moderate growth patterns. Improvement in plant height due to sulphur application is well known fact that the physiological role of sulphur in plant that sulphur nutrition 42 enhances vigorous root growth, cell multiplication, Sulphur plays a crucial role in promoting cell elongation and expansion in plants. It enhances chlorophyll synthesis, leading to a deeper green coloration of the leaves. This improvement in chlorophyll content increases the effective area available for photosynthesis, ultimately resulting in higher dry matter accumulation compared to sulphur-deficient plants. In addition, sulphur boosts the activity of meristematic tissues, contributing to increased plant height. The increase in height is primarily attributed to enhanced cell division and elongation stimulated by sulphur application. Furthermore, the presence of sulphur facilitates the metabolism of mineral nitrogen, sulphur, and carbohydrates synthesized in the green tissues into amino acids, and eventually into proteins. This efficient conversion supports faster plant growth and development, thereby significantly increasing overall plant height.

Table 1: Effect of different levels of sulphur on plant height of mustard

Treatment's	Combinations	Plant Height (cm) 30 DAS
T_1	Control	13.33
T_2	NPK 40:60:40 + 15 kg sulphur/ha	15.14
T_3	NPK 40:60:40 + 20 kg sulphur/ha	15.62
T_4	NPK 40:60:40 + 25 kg sulphur/ha	16.60
T_5	NPK 40:60:40 + 30 kg sulphur/ha	18.62
T_6	NPK 40:60:40 + 35 kg/sulphur ha	19.45
T_7	NPK 40:60:40 + 40 kg sulphur ha	16.47
T_8	NPK 40:60:40 + 45 kg sulphur/ha	17.52
T_9	NPK 40:60:40 + 50 kg sulphur/ha	17.85
T_{10}	NPK 40:60:40 + 55 kg sulphur/ha	17.83
SE		0.07
CD% 0.5		0.16

Treatment's	Combinations	Plant Height (cm) 60 DAS
T_1	Control	115.59
T_2	NPK 40:60:40 + 15 kg sulphur/ha	116.42
T_3	NPK 40:60:40 + 20 kg sulphur/ha	118.24
T_4	NPK 40:60:40 + 25 kg sulphur/ha	120.34
T_5	NPK 40:60:40 + 30 kg sulphur/ha	124.47
T_6	NPK 40:60:40 + 35 kg/sulphur ha	125.57
T_7	NPK 40:60:40 + 40 kg sulphur ha	123.83
T_8	NPK 40:60:40 + 45 kg sulphur/ha	123.93
T_9	NPK 40:60:40 + 50 kg sulphur/ha	123.46
T_{10}	NPK 40:60:40 + 55 kg sulphur/ha	122.45
SE		0.20
CD% 0.5		0.46

Treatment's	Combinations	Plant Height (cm) 90 DAS
T_1	Control	151.27
T_2	NPK 40:60:40 + 15 kg sulphur/ha	152.59
T_3	NPK 40:60:40 + 20 kg sulphur/ha	161.54
T_4	NPK 40:60:40 + 25 kg sulphur/ha	162.57
T_5	NPK 40:60:40 + 30 kg sulphur/ha	163.83
T_6	NPK 40:60:40 + 35 kg/sulphur ha	167.67
T_7	NPK 40:60:40 + 40 kg sulphur ha	163.50
T_8	NPK 40:60:40 + 45 kg sulphur/ha	161.33
T_9	NPK 40:60:40 + 50 kg sulphur/ha	161.96
T_{10}	NPK 40:60:40 + 55 kg sulphur/ha	154.76
SE		0.39
CD% 0.5		0.82

2. No. of Leaves: The results pertaining to the effect of application different levels of sulphur on number of trifoliate leaves per plant of mustard are presented in Table 2 Number of leaves per plant of mustard observed at 30 and 60 DAS showed statistically significant differences present among various doses of combination applied. The number of mustard leaves per plant at 30 and 60 DAS showed statistically significant differences across the different combination dosages used. Following treatment T_6 (40:60:40 NPK + 35 kg sulphur ha-1), followed by treatment T_5 (40:60:40 NPK + 30 kg sulphur ha-1), the highest number of leaves per plant (6.21, 17.88 leaves) was recorded at 30 and 60 DAS, respectively. In T_1 (control), the smallest number of leaves per plant (4.67 and 66.25 leaves) was noted at 30 and 60 DAS, respectively.

Table 2: Effect of different levels of sulphur on number of leaves per plant

Treatment's	Combinations	30 DAS	60 DAS
T_1	Control	4.67	16.25
T_2	NPK 40:60:40 + 15 kg sulphur/ha	5.43	16.70
T_3	NPK 40:60:40 + 20 kg sulphur/ha	5.47	17.22
T_4	NPK 40:60:40 + 25 kg sulphur/ha	5.56	17.51
T_5	NPK 40:60:40 + 30 kg sulphur/ha	6.21	17.88
T_6	NPK 40:60:40 + 35 kg/sulphur ha	6.65	18.70
T_7	NPK 40:60:40 + 40 kg sulphur ha	5.65	17.46
T_8	NPK 40:60:40 + 45 kg sulphur/ha	5.44	17.26
T_9	NPK 40:60:40 + 50 kg sulphur/ha	5.16	17.21
T_{10}	NPK 40:60:40 + 55 kg sulphur/ha	5.13	16.87
SE		0.09	0.04
CD% 0.5		0.20	0.14

3. No. of Branches: The results pertaining to the effect of application different levels of sulphur on number of branches per plant in mustard are presented in Table 3 Number of branches per plant in mustard showed statistically significant differences present among various doses of combination applied. The maximum number of branches per plant (3.57, 10.42 and 13.77 branches) was observed with treatment T_6 (40:60:40 NPK + 35 kg sulphur ha-1), followed by T_5 (40:60:40 NPK + 30 kg sulphur ha-1), with 3.22, 9.96 and 12.09 branches observed at 30, 60 and 90 DAS. Minimum number of branches per plant (8.56 and 12.78 branches) was observed in T_1 (Control).

Table 3: Effect of different levels of sulphur on number of branches per plant in mustard in mustard.

Treatment's	Combinations	30 DAS	60 DAS	90 DAS
T_1	Control	2.33	8.32	10.62
T_2	NPK 40:60:40 + 15 kg sulphur/ha	2.47	8.55	11.22
T_3	NPK 40:60:40 + 20 kg sulphur/ha	2.73	9.25	11.36
T_4	NPK 40:60:40 + 25 kg sulphur/ha	2.78	9.35	12.09
T_5	NPK 40:60:40 + 30 kg sulphur/ha	3.22	9.96	12.63
T_6	NPK 40:60:40 + 35 kg/sulphur ha	3.57	10.42	13.77
T_7	NPK 40:60:40 + 40 kg sulphur ha	3.24	9.95	12.16
T_8	NPK 40:60:40 + 45 kg sulphur/ha	2.98	9.75	12.14
T_9	NPK 40:60:40 + 50 kg sulphur/ha	2.95	9.52	11.20
T_{10}	NPK 40:60:40 + 55 kg sulphur/ha	2.91	8.80	11.12
SE		0.03	0.09	0.10
CD% 0.5		0.07	0.20	0.15

Discussion

Among the growth parameters, plant height and root length were studied at 30, 60, and 90 days after sowing. Both plant height and the number of branches increased steadily with plant age, showing a continuous upward trend up to 90 days of observation. This progressive growth may be attributed to the natural development processes of the plant, particularly in branching and vegetative expansion during active growth phases. Regarding nutrient influence, the application of sulphur, particularly up to 35 kg/ha, significantly enhanced plant height, leaf number, and branching. These improvements in growth parameters can be attributed to the increased availability of sulphur in the soil, which plays a crucial role in stimulating plant growth. Sulphur's positive effect on shoot height may be due to its essential role in cell division. Additionally, sulphur is known to support the activity of meristematic tissues, promoting the development of shoots and leaves. The beneficial effects of sulphur were most pronounced at the application rate of 35 kg S/ha.

It is as well as known fact that plants absorb all the essential plant nutrients from soil solution in a balanced requirement quantity, and even if certain nutrients are added in excess of the plants requirement, the plant growth is likely to sulphur supported by Verma and Dawson (2019) [11] and Halder *et al*. (2007) [10] Phosphorus plays a crucial role in branch development and the translocation of photosynthates. As a key constituent of nucleic acids, phytin, and phospholipids, its application has been shown to increase both plant height and the number of branches per plant. The varied response to phosphorus can be attributed to its efficiency and mode of fertilization, which may be influenced by environmental factors, as supported by Verma and Dawson (2019) [11] and Halder *et al*. (2020) [10].

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