# Effect of Sulfur Application on Growth and Yield of Mustard *(Brassica juncea* L.*)* in Arunachal Pradesh, India

**Thesis**

Submitted to the
**Rajiv Gandhi University, Rono Hills, Doimukh**
in partial fulfilment of the requirements
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**Master of Science (Agriculture)**

**In**

**Agronomy**

by


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**January2023**

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**Arunachal Pradesh**

# CERTIFICATE – I

Certified that Mr. Dani Haghu {Admission No.: 20AGRN04, Registration No. 46-M.Sc./AGR/2020-21} has satisfactorily completed his course of research for a period of not less than two semesters and that the thesis entitled "**Effect of Sulfur Application on Growth and Yield of Mustard** *(Brassica juncea* L.*)* **in Arunachal Pradesh, India**" submitted by him to the Rajiv Gandhi University, Doimukh – 791 112 (Arunachal Pradesh) in partial fulfillment of the requirements for the award of the degree of Master of Science (Agriculture) in the subject of Agronomy is the result of original research work conducted by her under my supervision and is sufficient of a high standard to warrant its presentation to the examination.

I also certify that the thesis or part thereof has not been previously submitted by her for a degree from any University.

Date: (Prof. Sumpam Tangjang)

Chairperson

**Rajiv Gandhi University**
**Rono Hills, Doimukh- 791 112, Papum Pare,**
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# CERTIFICATE – II

This is to certify that the thesis entitled "**Effect of Sulfur Application on Growth and Yield of Mustard** *(Brassica juncea* L.*)* **in Arunachal Pradesh, India**" submitted by Mr. Dani Haghu {Registration No.: 46-M.Sc./AGR/2020-21} to Rajiv Gandhi University, 791112 (Arunachal Pradesh) in partial fulfillment of the requirements for the award of the degree of Master of Science (Agriculture) in Agronomy has been approved by the Student's Advisory Committee after an oral examination jointly with an External Examiner.

| Name | | Designation | Signature |
|---|---|---|---|
| 1. | …………………………………….. | External Examiner | |
| 2. | Prof. Sumpam Tangjang | (Dean) | |
| 3. | Prof. Sumpam Tangjang | Chairman (Advisory Committee) | |
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| 5. | Dr. Bai Koyu | Member (Advisory Committee) | |
| 6. | Dr. Tadung Taku | Member (Advisory Committee) | |

# DECLARATION

I hereby declare that the thesis entitled "**Effect of Sulfur Application on Growth and Yield of Mustard** *(Brassica juncea* L.*)* **in Arunachal Pradesh, India**" is an authentic record of the work done by me and that no part thereof has been presented for the award of any other degree, diploma, associateship, fellowship or any other similar title.

Place: Doimukh (Dani Haghu)

Date: Student

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Place: Doimukh (Dani Haghu)
Student Date:

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| | |
|---|---|
| % | Per cent |
| / | Per |
| @ | At the rate |
| B:C | Benefit cost ratio |
| cm | Centimetre |
| m | Metre |
| DAS | Days after sowing |
| EC | Electrical conductivity |
| *et al.* | Et alia (And others) |
| Fig. | Figure |
| g | Gram |
| ha | Hectare |
| hrs | Hours |
| i.e. | Id est (that is) |
| kg | Kilogram |
| $k_2O$ | Potash |
| m ha | Million hectare |
| a.i. | Active ingredient |
| N | Nitrogen |
| No. | Number |

| | |
|---|---|
| °C | Degree centigrade |
| pH | Puissance de hydrogen (Potential of hydrogen) |
| cv. | Cultivated variety |
| $P_2O_5$ | Phosphate |
| q | Quintal |
| RDF | Recommended dose of fertilizer |
| S | Sulfur |
| C.D | Critical Difference. |
| SEm± | Standard error of mean. |
| SMW | Standard Meteorological Week |
| EC | Emulsifiable concentrate |
| SL | Soluble (liquid) concentrate |
| T | Tonnes |
| Viz. | Namely |
| Rs | Rupees |
| FYM | Farm Yard Manure |
| S | Sulfur |
| RSQI | Residual Soil Quality Index |
| FP | Farmer’s practice |
| RBD | Randomized Block Design |
| CEC | Cation Exchange Capacity |

| | |
|---|---|
| RUE | Radiation Use Efficiency |
| WUE | Water Use Efficiency |
| ET | Evapotranspiration |
| AET | Actual Evapotranspiration |
| IPAR | Intercepted Photosynthetic Active Radiation |
| IW/CPE | Irrigation water/Cumulative Pan-evaporation |
| RNR | Relative Net Return |
| RVT | Relative Value Total |
| LAI | Leaf Area Index |
| H.I. | Harvest Index |

# ABSTRACT

The research involves the experiment entitled "**Effect of Sulfur (S) Application on the Growth and Yield of the Indian mustard (*Brassica juncea* L.)** in Arunachal Pradesh, India". The experiment was conducted during the *rabi* season of 2022-23 at Agricultural farm, Karsingsa, Papum Pare district, under Rajiv Gandhi University, Rono Hills, Doimukh. The soil of the experimental site was well drained, sandy loam in texture, and slightly acidic in nature. The experiment was laid out in Randomized Block Design with 3 replications. Treatments comprised of four level of Sulfur i.e., 0, 20, 40 and 60 kg $ha^{-1}$. The experimental data on growth, yield, and yield attributing characters were recorded at 30, 60, and 90 days after sowing. All data were subjected to Analysis of Variance (ANOVA), F-test was carried out to test its significance at $P \leq 0.05$. Result indicated that with the increment of S doses by 20 kg $ha^{-1}$ up to 60 kg $ha^{-1}$ ($T_4$) evenly affected the growth parameters like plant height, number of branches per plant, number of leaves per and dry matter production. At 90 DAS, among the different treatments maximum fresh weight was recorded in $T_4$ (63.94 g) and minimum fresh weight in $T_1$ (62.55 g). Highest number of seeds per siliquae was recorded with the application of 60 kg S $ha^{-1}$ in $T_4$ (128.18). The maximum gross return and net return was observed in $T_4$ ₹83,000 and ₹43,000 with benefit cost ratio (1.3) whereas minimum mean gross income ₹45,000, net return ₹1,5000.

Understanding the relationship between S and mustard is of paramount importance for optimizing crop management practice. In conclusion, the study underscores the significant influence of S level on mustard where the dose of S (60 kg $ha^{-1}$) may be the most economical and favourable dose that would give a higher yield with a higher net return and benefit: cost ratio. Further research in this area could pave the way for targeted interventions to maximize mustard production while minimizing resource inputs.

**Keywords:** Mustard, Sulfur, Growth, Yield

**CHAPTER–I**

# INTRODUCTION

India is the third largest producer of rapeseed mustard having 5.90 million hectares area with 6.41 million tonnes production, but the average yield of rapeseed-mustard in India is only 1145 kg $ha^{-1}$ (Economic survey 2013). Indian mustard (*Brassica juncea* L.) is an important oil seed crop, belonging to the family Cruciferae which is cultivated throughout the world to produce edible vegetable oil, spices and condiments for consumption of humans and feed for livestock. Globally, in the year 2018-19, rapeseed mustard was cultivated in about 36.5 million hectares (m ha) and the estimated production and yield 72.3million tonnes and 1.98 tonnes $ha^{-1}$, respectively. In India it is popularly known as Rai and is an important *rabi* season oilseed crop of North India. Annually, India contributes about 11.61% of the total production in the world (FAS USDA, 2020). It accounts for 21% of the total oilseeds is area and 23% of the total oilseeds production in the country (GOI 2007–08). India had an annual production of 9.3 MT from 6.1 M ha area with yield average of 1511 kg $ha^{-1}$ in the year 2018-19 (GOI, 2020). According to the available data, production as well as productivity increased significantly from year 2010-11 to 2018-19. The production grew from 61.6 MT to 72.4 MT whereas the productivity also increased to 1980 kg $ha^{-1}$ from 1840 kg $ha^{-1}$ (DRMR 2020). Sulfur application is expressed on yield and oil content of produce. It is involved in the synthesis of essential amino acids, like cysteine, cystine and methionine (Kumar & Yadav 2007).

In India, the oilseed Brassica is the second most important oilseed crop next only to groundnut, and account for about 30 percent of the total oil seeds produced in the country. The rapeseed mustard oil has lowest amount of the saturated fatty acids as compared to any other vegetable oil. It also contains adequate amounts of the two essential fatty acids, linoleic and linolenic that are not synthesized by human body and need to be supplied to the human diet from external sources. The oil free meal is a good source of proteins, well balanced in amino acids and minerals. The presently cultivated Indian varieties of rapeseed mustard, however, have high amounts (40-45 percent) of long carbon chain fatty acids, particularly erucic acid (22:1), in their seed oil and high amounts of sulfur (S) containing compounds, *viz.,* glucosinolates (80 160 mg $g^{-1}$), in their oil free meal, as against the internationally accepted level of less than 2% erucic acid in the seed oil and less than 30 mg $g^{-1}$ gluco-3-inolate in oil free meal (Downey 1990). Fertilization of nitrogen and sulfur have better response with respect to yield, oil content and quality parameters. A liberal supply of available nutrients is essential for getting higher yield and better quality of rapeseed and mustard. It is, therefore, essential to carry out research on soil fertilizer complex for ascertaining the nutritional requirement of this crop.

Sulfur deficiencies in India is widespread and scattered. Deficiency of sulfur in Indian soils is on rise due to intensification of agriculture with high yielding varieties and multiple cropping

2coupled with the use of high analysis sulfur free fertilizers along with restricted or no use of organic manures, have resulted in depletion of the soil sulfur reserve. Application of different sulfur fertilizers at 10-50 kg S $ha^{-1}$ significantly increased the seed yield of rapeseed and mustard crops ranging from 5.2-26.7% as compared to control (Ahmad *et al*., 2005). Oil content in mustard is reduced due to application of high analysis fertilizers. The chemical fertilizers being used for supplementing the major nutrient are generally either deficient or low in sulfur content. Di-ammonium phosphate used as phosphorus source in place of single super phosphate leads to S deficit in soil. In sulfur deficient soil, the efficiency of applied NPK fertilizers may be seriously affected and crop yield may not be sustainable (Ahmad *et al*., 2005). The importance of sulfur fertilization for increasing yield and quality of Indian mustard is being increasingly recognized. However, the information regarding optimum level of sulfur as well as source of sulfur and its influences on seed yield and quality of mustard is meager. Probably for these reasons mustard crop needs comparatively higher amount of sulfur for proper growth and development and higher yields. Sulfur levels significantly influenced the seed and stover yield of mustard (Sharma *et al.,* 2009).

Since adequate information is lacking on the choice of sulfur fertilizers for mustard, this investigation was undertaken to find out the suitability of various levels and sources of sulfur for mustard grown in Arunachal Pradesh. Keeping these points in view, the present investigation "**Effect of Sulfur on growth and yield of mustard (*Brassica juncea* L.)**" was carried out with the following objectives:

i. To study the effect of growth and yield parameters of mustard.
ii. To study the economics of mustard production.

**CHAPTER–II**

# REVIEW OF LITERATURE

This chapter presents a brief review of research accomplishments made at various places on different fields related to this investigation under the various headings.

## 2.1 Effect of source of S on growth parameters of mustard

Agarwal *et al*. (2000) found that *Brassica juncea* gave the better response to 40 kg S $ha^{-1}$ which increased the biomass accumulation and LAI in mustard.

Ahmad *et al.* (2005) reported that S application at different growth stages in mustard increased the growth and yield attributes significantly up to 40 kg S $ha^{-1}$.

Choudhary *et al*. (2003) reported that application of S significantly increased the mustard seed and stover yield up to 60 kg S $ha^{-1}$ and the highest yield of seed and stover was obtained with 60 kg S $ha^{-1}$.

Dongarkar *et al*. (2005) reported that various doses of S (0, 20, 40 kg S $ha^{-1}$) and nitrogen (0, 25, 50, 75 kg N $ha^{-1}$) significantly influenced the growth of mustard. Plant height, number of branches, dry matter production was found significantly more with 75 kg N $ha^{-1}$ and 25 kg S $ha^{-1}$ over rest of the doses.

Dubey and Khan (1993) reported that application of S up to 30 kg $ha^{-1}$ significantly increased the dry matter in mustard at all the stages of crop growth starting from 30 DAS to at harvest.

Giri *et al*. (2006) reported the higher values of growth parameter of mustard with the application of 60 kg S $ha^{-1}$.

Kumar *et al.* (2001) reported that plant height, primary and secondary branches per plant were significantly higher with the application of 40 kg S $ha^{-1}$ as compared to the control and 20 kg S $ha^{-1}$.

Maurya (1995) observed that application of S in mustard at the rate of 40 kg S $ha^{-1}$ increased the plant height and number of branches plant per plant.

Mohan and Sharma (1992) carried out a field experiment and observed that plant growth of mustard was increased up to the application of 50 kg S $ha^{-1}$.

Om Prakash *et al.* (2002) stated that highest number of branches $plant^{-1}$ was observed with increase in S rate up to 40 kg $ha^{-1}$.

Piri *et al.* (2006) observed that increasing rate of S significantly increased the plant height, dry matter accumulations up to 45 kg S $ha^{-1}$ in mustard.

Ramesh *et al.* (2006) reported that four levels of S (0.0, 32.5, 65.0 and 97.5 kg S $ha^{-1}$) were applied through gypsum and observed that S application significantly increased the number of primary branches $plant^{-1}$ in mustard.

Sharma *et al.* (1991) reported that application of S at the rate of 60 kg S $ha^{-1}$ enhanced the primary branches per plant in mustard.

Singh and Dhiman (2005) reported that leaf-area index, number of primary branches per plant and dry weight per plant(g) were increased with increasing rate of S from 0 to 45 kg $ha^{-1}$ in mustard.

Singh and Kumar (1996) reported that application of S at the rate of 40 kg $ha^{-1}$ significantly increased the plant height of Indian mustard as compared to 0 and 20 kg S $ha^{-1}$.

Singh and Saran (1993) reported that application of S at the rate of 30 kg $ha^{-1}$ significantly increased the plant height and leaf-area index of toria. However, in these parameters no significant difference was recorded at 30 and 60 kg S $ha^{-1}$.

Sudhakar *et al.* (2002) reported that application of S @ 60 kg $ha^{-1}$ significantly improved plant height and primary and secondary branches over the lower doses of S.

## 2.2 Effect of source of S on yield attributes and yield of mustard

Debnath *et al.* (2014) reported that the seed yield on average was 14.5% higher in elemental S over the control which further increased to 30.6% along with inoculated S oxidizers.

Singh *et al.* (2015) conducted an experiment on clay loam soil to study the effect of varieties, sources and levels of S on yield, nutrient uptake and economics of Indian mustard [*Brassica juncea* (L.) Czern and Cosson] and revealed that S fertilization upto 90 kg $ha^{-1}$ gave significantly higher seed (1711 kg $ha^{-1}$) and straw yield (5517 kg $ha^{-1}$) over other treatments.

Singh and Kumar (2014) reported that application of 120 kg N $ha^{-1}$ and 45 kg S $ha^{-1}$ was the best combination for getting higher seed yield, siliquae $plant^{-1}$, siliquae length, number of seed $siliquae^{-1}$and harvest index.

Parihar *et al.* (2014) carried out a study on effect of S and fortified vermicompost on growth and yield of mustard *Brassica juncea* (L) with sixteen treatment combinations comprising four levels of each S and fortified vermicompost and revealed that progressive increase in levels of S from control to 40 kg $ha^{-1}$ resulted in significant improvement in growth and yield attributes.

Baudh *et al.* (2012) found that growth and productivity increased with increasing level of S and Zn. Application of the S and Zn were highly influenced with the application of 60 kg S ha$^{-1}$ in the combination. The root length, shoot length, number of leaves plant$^{-1}$, number of branches plant$^{-1}$ and crop growth rate were much influenced on this combination. The productivity of such as biomass production, number of capsules, seed output and reproductive capacity with grain biological yield also increased with increasing level of S and Zn.

Jyoti *et al.* (2012) observed that the highest seed and stover yield of rapeseed (cv 'B-9') was 910 and 4320 Kg ha$^{-1}$, respectively under the application of 30 Kg S ha$^{-1}$ through SSP, resulting in a 41.9 and 18.9% increase in the yield over that of the control. However, the highest benefit : cost (1.77) was recorded with the foliar application of 1% S-52 (liquid fertilizer) at 20 DAS, vegetative growth stage (35 DAS) and pre flowering stage (50 DAS).

Kumar and Trivedi (2012) reported the seed and straw yields, oil content and protein content significantly increased with increasing level of S up to higher level of 60 kg S ha$^{-1}$. Further application of 20, 40 and 60 kg S ha$^{-1}$ increased the seed yield over the control by 13.95, 28.11 and 28.47%, respectively.

Singh *et al.* (2012) found that the variety 'Rohini' gave higher plant height, number of branches per plant, siliquae per plant, seed per siliquae, 1000 grain weight, harvest index and resulted significantly higher seed and stover yield, oil and protein content than 'Bio-902' and 'Kranti'. The application of 60 kg S ha$^{-1}$ gave significantly higher grain yield and quality (protein and oil content in seed) over all other levels of S application and the control.

Thuan *et al.* (2010) reported from IARI, New Delhi application of S @ 40 kg ha$^{-1}$ produced 19.3% higher seed yield than control plot.

Verma *et al.* (2011) observed that fertilizers 120 kg N + 45 kg S ha$^{-1}$ gave significantly higher plant height, number of primary branches per plant, number of secondary branches plant, dry matter accumulation per plant, siliquae length, number of siliquae per plant, number of seeds per siliquae, 1000 seed weight, grain yield, stover yield, harvest index and protein content (%) than other levels of fertilizers (control, 40 N + 15 S and 80 N + 30 S kg ha$^{-1}$) during both the years. However, the application of moisture conservation practices (control, dust mulch creating by weeding at 25 and 35 DAS and organic mulch @ 5 t ha$^{-1}$ paddy straw at 25 DAS) increased growth, yield attributing characters and seed yield as well as nutrient content and uptake by mustard over the control. On the basis of economics 120 kg N+45 kg S ha$^{-1}$ and organic mulch @ 5 t ha$^{-1}$ at 25 DAS were found most profitable.

Verma *et al.* (2012) reported that application of 60 kg S ha$^{-1}$ gave significantly higher seed and oil yield.

Basumatary and Talukdar (2011) worked on sandy loam soil of Jorhat and found that different levels of S had significant influence on oil content in seeds of rapeseed. Oil content in the seeds significantly increased from 37.5 to 41.1% with increase in S levels from 0 to 60 kg S ha$^{-1}$.

Ahmad *et al.* (1998) reported a strong positive correlation between S and lipid content in seed of Brassica campestris cultivated variety 'Pusa Bold'. They obtained increase in oleic acid (18:1) and reduced erucic acid (22:1) contents due to application of S up to 40 kg ha $^{-1}$.

Ali *et al.* (1996) recorded increased in plant height and branches per plant due to S application @ 30 kg S ha$^{-1}$.

Tiwari *et al.* (2003) reported that significant higher yield of mustard at farmers field by using S at different doses viz. 20, 30 and 40 kg S ha$^{-1}$.

Aulakh and Pasricha (1997) reported that among oil seed crops, rape seed and mustard have highest requirement of S with the optimum level ranging from 20 to 60 kg S ha$^{-1}$.

Chauhan *et al.* (1996) found that the graded levels of S from 0-50 kg S ha$^{-1}$ significantly increased yield attributes and yield with maximum siliquae plant$^{-1}$, seeds siliquae$^{-1}$, 1000 seed weight and seed yield of mustard on the application of 40 kg S ha$^{-1}$.

Giri *et al.* (2003) found that application of 45 kg S ha$^{-1}$ resulted in the highest oil content of 41-44 %. S application @ 20 kg ha$^{-1}$ increased oil content in mustard over the control.

Giri *et al.* (2006) reported that application of 60 kg S ha$^{-1}$ produced significantly higher seed yield of mustard.

Jat *et al.* (2008) reported that application of 40 kg S + 25 kg $ZnSO_4$ + 50 kg $FeS_{04}$ ha$^{-1}$ significantly increased the number of siliquae plant$^{-1}$, number of seeds siliquae$^{-1}$, test weight, seed yield and stover yield of mustard.

Kumar and Yadav (2007) reported that the seed, stover yields and oil content were significantly influenced by different phosphorus and S levels. The highest seed yield, stover yield and oil content were recorded at 39.3 kg P ha$^{-1}$ and 45 kg S ha$^{-1}$, which were on a par with those at 26.2 kg P ha$^{-1}$ and 30 kg S ha$^{-1}$, and these were significantly superior to the control.

Umar *et al*. (1997) reported that increase in seed yield of mustard 'T-59' (Varuna) with 60 kg S ha$^{-1}$ at Bikaner.

Kumar *et al.* (2001) reported that the application of 40 and 60 kg S ha$^{-1}$ being at par with each other gave significantly higher yield and quality (protein and oil contents in seed) over 20 kg S ha$^{-1}$ and control. The growth and yield contributing characters showed a similar trend.

Mishra (2003) showed that mustard responded significantly at 40 kg S ha$^{-1}$ and was

27.59% higher in seed yield and 37.64% higher in stover yield as compared to the yields at the control. Basal application of S at the rate of 40 kg $ha^{-1}$ increased the seed yield of mustard by 21.8% over basal application of N at the rate of 20 kg $ha^{-1}$ (Vyas et al., 2006). These studies reported that yield of mustard was increased with 20 to 60 kg S $ha^{-1}$ depending upon soil and environmental conditions.

Naik and Rao (2004**)** recorded highest oil content of 40.8% following application of 40 kg S $ha^{-1}$ as pyrite + farmyard manure. Further, application of S at 30 kg $ha^{-1}$ as SSP recorded the highest crude protein content of 25.4% and resulted in 14.3% increase over the control during both the years. The results of this investigation find support from Kumawat *et al*. (2004).

Patel and Shelke (1998) reported that application of S up to 75 kg $ha^{-1}$ increased plant height, branches per plant and leaf area at 60 days after sowing.

Rajput and Yadav (1997) reported that higher yield of mustard cultivar 'Pusa Bold' and 'Pusa Bahar' up to 40 kg S $ha^{-1}$.

Raut *et al*. (1999**)** observed that application of S @ 40 kg $ha^{-1}$ resulted in the highest dry matter production. The chlorophyll and soluble protein concentration and rate of photosynthesis were highest with 100 kg N $ha^{-1}$ and 50 kg S $ha^{-1}$.

Sharma and Mehra (2005) reported that the pods $plant^{-1}$, pod length, seed $pod^{-1}$, test weight and yield (seed and stover) significantly increased with each successive increase in S level from 0 to 60 kg S $ha^{-1}$.

Singh and Nad (2000) reported that yield of mustard increased significantly when 60 kg S $ha^{-1}$ was applied along with N @ 120 kg $ha^{-1}$.

Withers and Odonnell (1994**)** reported that seed yield of double-row winter oilseed rape was significantly improved by S application by 10-17% on sandy soils with severe S deficiency symptoms, while seed yield was consistently but not significantly increased by an average of 8% on a shallow calcareous soil which did not show S deficiency symptom.

Shekhawat *et al*. (1996) reported that pyrite application reflected in higher yield as compared to gypsum application in cluster bean in the experiment by. The effect of S on the yield was significant as reported by McGrath and Zhao (1996). Application of S helped in improvement in yield attributes of Indian mustard. These results corroborated with the findings of (Chauhan *et al.,* 1996).

Sarmah and Debnath (1999) reported that S fertilization significantly improved most of the yield attributes and seed yield (20.1%) as compared to control plot. Application of gypsum and bentonite S indicated their superiority in increasing the seed yield over pyrite. Significantly higher number of branches per plant, $siliquae^{-1}$, test weight of seeds, seed yield and stover yield were observed due to application of gypsum or bentonite S as compared to pyrite. Average increase of seed yield over control was 12.9, 29.5 and 32.2% due to application of pyrite, gypsum and bentonite S, respectively. High response to gypsum in respect of seed yield might be due to its readily available $SO_4$, S and high calcium content, whereas pyrite might had further acidified effect. The difference in seeds per siliquae and seed weight$^{-1}$ failed to bring any marked change due to use of different sources of S.

Rao and Shaktawat (2002) reported that gypsum application (250 kg ha$^{-1}$) reflected in significant improvement in yield attributes and seed yield of Indian mustard (*Brassica juncea* L.). Among the sources of S, gypsum proved significantly superior with respect to yield attributes (pods plant$^{-1}$ and grain weight), grain and straw yield and harvest index in lentil in the experiment by Singh and Chauhan (2002).

Prasad *et al.* (2002) reported that gypsum application reflected in significant improvement in yield of groundnut. Powdered elemental S was available to plant sooner than an elemental S fertilizer, but neither as quickly as gypsum.

Kowalenko (2004) investigated on the response of forage grass to S applications on coastal British Columbia soil. Gypsum was used as a S fertilizer in the production of winter oilseed rape (*Brassica napus* L. var. *napus*). Sources of S like gypsum and cosavet did not differ significantly with regard to seed and stover yield of mustard (Piri and Sharma, 2006). The increase in seed yield due to S application in mustard was also reported by Piri and Sharma (2006).

Tomar *et al*. (2007) reported that application of 30 kg S ha$^{-1}$ significantly improved the yield attributes, seed and stover yields of mustard.

Singh and Singh (2007) reported that the seed and stover yields of linseed increased significantly when S was applied through gypsum as compared to the other sources of S. This increase in yield might be attributed to easy availability of $SO_4^{-2}$ present in gypsum as compared to sulphide form in pyrite, which essentially requires its oxidation to be converted into $SO_2$ prior to its absor4ption by the crop.

Makeen *et al*. (2008) reported that S application @ 60 kg ha$^{-1}$ caused cent per cent increase in yield over control.

Khatkar *et al*. (2009) reported that a greater number of siliquae$^{-1}$, seed per siliquae and the test weight was also recorded with higher levels of these factors which ultimately resulted in higher seed yield.

Sharma *et al*. (2009) observed that the mustard seed yield increased significantly by 33% to 141% over control with the application of S. Significant improvement in the number of siliquae$^{-1}$, test weight, seed yield and stover yield was recorded with S fertilization as compared to control.

Chattopaddhyay and Ghosh (2012) reported that sources viz. single superphosphate, phosphogypsum, pyrites and elemental S have significant influence on grain yield and total biological yield. The maximum grain yield was recorded with SSP followed by phosphogypsum and pyrite. The lowest yield was observed with elemental S. Amongst the various sources of S tested, single superphosphate was the best with respect to grain yield followed by phosphogypsum, pyrites and elemental S.

Kumar and Trivedi (2012) reported that the highest seed and straw yields were observed with use of ammonium sulphate which was significantly higher over other sources. The maximum seed and straw yields were recorded with the application of ammonium sulphate followed by gypsum, single super phosphate and pyrite.

Rao *et al*. (2013) reported that S application significantly influenced the yield attributing characters and yield over control. Application of S @ 45 kg $ha^{-1}$ through gypsum recorded highest number of filled pods per plant, 100 pod weight, 100 kernel weight, pod yield, haulm yield of the kernels. Application of gypsum at 45 kg $ha^{-1}$ has increased the pod yield to the tune of 52.2%.

Katiyar *et al*. (2014) reported that basal application of S 90 % DP @ 25 kg $ha^{-1}$ had significant influence on yield attributes and grain yield of mustard. Maximum value of seeds per pod, thousand grain weight and grain yield were recorded with dual application basal along with 80% WP @ 1.25 kg $ha^{-1}$ foliar sprayed at 75 DAS closely followed by application of S as basal + 80% WP @ 5 kg $ha^{-1}$ applied with urea broadcasting at 45 DAS and minimum value under farmer's practice.

**2.3 Effect of source of Sulfur on quality of mustard**

Nuttall *et al*. (1987) observed that with increase of S application, the percentage of canola seed oil showed significant increase as compared to control. The superiority of single superphosphate and phosphogypsum over pyrites and elemental S with regards to oil content might be due to higher solubility of single superphosphate and phosphogypsum resulting in easily available forms of S. S plays the role in formation of glucosides, which on hydrolysis produce higher amount of oil as well as allylisothiocyanate, which are responsible for pungency, a determinative factor of oil quality (Sharma *et al*., 1991). S fertilization significantly improved the oil content of mustard as compared to control (Tandon, 1991).

McGrath and Zhao (1996) reported that gypsum application at sowing positively impacted oil content.

Ghosh *et al.* (1999)) also reported the highest oil content by the application of S in the range of 45-50 kg $ha^{-1}$ in mustard crop.

Sarmah and Debnath (1999) reported that S fertilization significantly improved the oil content (2.5%) as compared to no S application. They found that the difference in oil content of mustard failed to bring any marked change due to use of different sources of S. Gypsum and bentonite S were found to be better source as compared to pyrite.

Panda *et al.* (2000) agreed with results on findings of increased oil content with increasing level of S. There was significant difference between two sources of S, whereas cosavet gave significantly higher oil content than gypsum. The results are in agreement with the findings of Chauhan *et al.* (2002).

Singh *et al*. (2005) also observed that the oil content in mustard seed significantly increased 6.3% with 60 kg S $ha^{-1}$ over no S application.

Piri and Sharma (2006) reported that the increase in oil content with S application might be because of S role in oil synthesis, as S is a constituent of glutathione, a compound that plays a vital role in oil synthesis.

Mani *et al*. (2006) reported that application of S was found remarkably ameliorative on quality control of mustard plants leading to increased oil content.

Tomar *et al*. (2007) reported that application of 30 kg S $ha^{-1}$ significantly increased oil content.

Malhi *et al.* (2007) revealed that oil concentration in seed increased with S fertilization for all Brassica species. This also reflects in productivity of total oil content as highest with basal and foliar applied S and lowest content from control.

Singh and Singh (2007) reported that among sources of S, gypsum proved significantly superior to other sources for oil content of linseed.

Faujdar *et al*. (2008) reported that application of S proved beneficial in increasing oil content.

Vaseghi *et al*. (2011) reported that canola cultivars reacted to S fertilizer and oil concentration in their seed increased.

Kumar and Trivedi (2012**)** reported that the highest oil content of seed was observed with use of ammonium sulphate (39.2%) which was significantly higher over other sources followed by gypsum (38.5%), SSP (38.4%) and pyrite (38.0%), respectively.

Rao *et al*. (2013) reported that S application significantly influenced the oil content of mustard over control regardless of the sources and levels.

Sah *et al.* (2013) reported that application of S @ 45 kg $ha^{-1}$ increased the oil content of mustard as compared to control. These results are in close conformity with the findings of Mahapatra and Chandra (1992).

Katiyar *et al.* (2014) reported that application of S 90% DP @ 25 kg $ha^{-1}$ basal had significant influence on oil content of mustard. Maximum oil content (42.4%) was recorded with dual application of basal along with 80% WP @ 1.25 kg $ha^{-1}$ foliar sprayed at 75 DAS closely followed by application of S basal + 80% WP @ 5 kg $ha^{-1}$ applied with urea broadcasting at 45 days after sowing and minimum value under farmers practice.

**2.4 Mustard Economics**

Om *et al.* (2013) conducted an experiment on productivity and nutrient uptake of Indian mustard *Brassica juncea* (L.) influenced by land configuration and preceding and directly applied nutrients in green gram *Vigna radiata* (L.) and mustard cropping system under limited irrigation conditions on a sandy loam soil during 2010-11 and 2011-12 and reported that flat bed with mulch land configuration on an average fetched Rs. 14.8 × 103 $ha^{-1}$ and Rs. 12.35 × 103 $ha^{-1}$ more gross and net returns over flatbed method, respectively and thus had 0.44 more B: C ratio than flat bed. The higher seed yield with the corresponding stover yield and with minimal increase in cost of cultivation resulted in higher net returns and B: C ratio in flat bed with mulch land configuration.

Singh *et al.* (2015) studied the effect of varieties, sources and levels of S on yield, nutrient uptake and economics of Indian mustard *Brassica juncea* (L.) and revealed that S fertilization upto 90 kg $ha^{-1}$ gave significantly higher seed (1711 kg $ha^{-1}$) and straw yield (5517 kg $ha^{-1}$), total nutrient uptake of N (99.6 kg $ha^{-1}$), P (27.7 kg $ha^{-1}$), K (63.6 kg $ha^{-1}$) and S (13.8 kg $ha^{-1}$), net return (Rs. 24192 $ha^{-1}$).

Parihar *et al.* (2014) carried out the study on the effect of S and fortified vermicompost on growth and yield of mustard *Brassica juncea* (L.) and Sixteen treatment combinations comprising four levels of each S and fortified vermicompost were evaluated. Progressive increase in levels of S from control to 40 kg $ha^{-1}$ resulted significantly 10.47 and 30.4 per cent higher net returns (25913 Rs. $ha^{-1}$) than above levels of S.

Pandey *et al.* (2014**)** revealed that the effect of bed configuration, fertilizer levels and their placement methods on the productivity of long duration pigeon pea *Cajanus Cajan* (L.) fetched 18.6% more net return and higher benefit: cost ratio over flatbed method of planting.

Kumar *et al*. (2015) worked on performance of chickpea under different planting method, seed rate and irrigation level and noted the highest gross return (INR 48,514 $ha^{-1}$), net return (INR 24, 057 $ha^{-1}$) and B: C ratio (1.98) in 75 cm raised bed over flatbed system.

Kumar and Trivedi (2011) found that the maximum net return (Rs 25098 $ha^{-1}$) and BC ratio (3.73) were recorded at 40 kg S $ha^{-1}$.

CHAPTER–III

# MATERIALS AND METHOD

A field experiment titled **"Effect of Sulfur on the growth and yield of Indian mustard** *Brassica juncea* (L)" was conducted during the winter (rabi) of 2021-22 in Karsingsa, Papum Pare, Arunachal Pradesh, India. The detailed information on location, soil, climatic and weather condition recorded during the cropping season along with materials used and methods employed are described in this chapter

## 3.1 Location

The experimental field is located at Karsingsa, Papum Pare district, Arunachal Pradesh 27.14˚North latitude and 93.61˚ East longitude and the altitude of 1700 m above the Mean Sea Level (MSL). The climate of Karsingsa is humid subtropical. This area receives an annual rainfall of 3200 mm with hot and humid summer and cool winter.

## 3.2 Soil

The soil textural class of the experimental site was sandy-clay loam with high acidic pH. A composite soil sample (0-30 cm depth) was collected randomly from various place of the experimental field before fertilizer application with the help of soil auger. After mixing these samples thoroughly, a representative soil sample were collected.

## 3.3 Experimental design:

The field experiment was laid out in Random Block Design (RBD) with 3 replications. Each replication was divided into 4 treatment of 3 x 2 m size and was randomly allocated within the block of each replication. The detail of the layout is given below (Fig:3.1).

## 3.4 Varieties:

Crop: Indian mustard

Botanical name: *Brassica juncea* (L.)

Family: Brassicaceae.

Local Genotype procured from Sagalee, Papum Pare, Arunachal Pradesh was used in the experiment.

**3.5 Area**: Total field area was 6,213 $m^2$ whereas total sown area was 83.125 $m^2$ and plot area was 12 $m^2$.

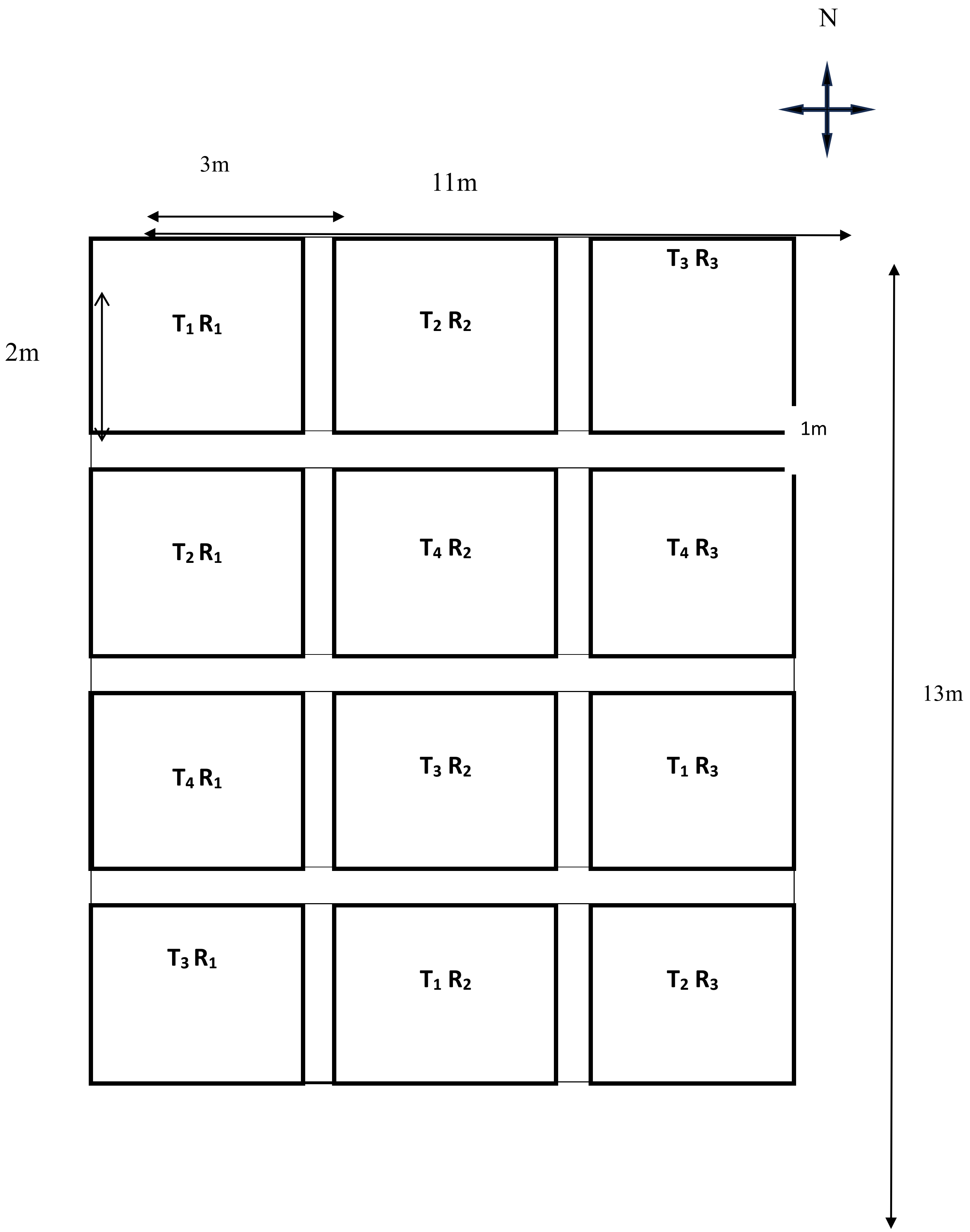


**Fig:3.1 The detailed layout of the Experimental plot**

**(M=meter, T= Treatment, R=Replication)**

### 3.6 Field operations

The experimental field was prepared by deep ploughing with tractor drawn disc plough followed by harrowing and planking to get a good tilth for proper germination and establishment of crop. The field was cleaned by hand picking stubbles of previous crops and weeds. The soil was uniformly mixed with vermicompost.

### 3.6.1 Seed rate and sowing:

Seeds were sown on $9^{th}$ January 2022, at the rate 5 kg $ha^{-1}$ in all the 12 treatments, i.e., spaced at 30 x 15cm and the seeds were sown manually with hand. Seeds were sown at the depth of 3-4 cm below the soil surface.

### 3.6.2 Fertilizer application:

Recommended dose of S was applied in the form of Sulfex powder to the crop. Three S levels 0, 30 and 60 kg $ha^{-1}$ were incorporated in 12 treatments. Sulfex 80%WP was applied as a basal according to treatment combinations.

### 3.6.3 Sowing

The seeds were sown directly in the field. A local genotype was selected for both the population dynamics and high growth rate. Seeds were sown 9/01/2022. Ridge and furrow type of layout was used for sowing seeds. The row to row and plant to plant spacing was kept at 30 and 15 cm respectively between the seeds.

### 3.7 Climate

The climate was predominated by hot and humid with the temperature ranging from 21°C-28°C and relative humidity of (67%-75%). Tabular and graphical representation of the meteorological parameter has been given below.

**Table 3.1: Weekly meteorological parameter during the period of experimentation from January 2022 to April 2022**

| SMW | Month and Date | Temperature (ºC) | | | Rainfall( mm) | Relative humidity (%) |
|---|---|---|---|---|---|---|
| | | Maximum | Minimum | Mean | | |
| 2 | Jan 09 – Jan 16 | 21.3 | 18.9 | 20.10 | 0.04 | 67 |
| 3 | Jan 17 – Jan 23 | 23.9 | 15.5 | 19.70 | 0.05 | 69 |
| 4 | Jan 24 – Jan 30 | 25.0 | 18.6 | 21.80 | 0.18 | 68 |
| 5 | Jan 31 – Feb 06 | 26.6 | 14.4 | 20.50 | 0.6 | 71 |
| 6 | Feb 07 - Feb 13 | 26.8 | 13.0 | 19.90 | 0.2 | 68 |
| 7 | Feb 14 – Feb 20 | 21.6 | 12.1 | 16.85 | 0.0 | 75 |
| 8 | Feb 21 – Feb 27 | 22.7 | 12.0 | 17.35 | 0.2 | 64 |
| 9 | Feb 28 – Mar 06 | 19.8 | 8.4 | 14.10 | 0.07 | 63 |
| 10 | Mar 07 - Mar 13 | 22.9 | 8.0 | 15.45 | 0.0 | 62 |
| 11 | Mar 14 – Mar 20 | 26.45 | 11.24 | 18.84 | 0.0 | 67 |
| 12 | Mar 21 – Mar 27 | 26.5 | 17.5 | 22.00 | 0.2 | 68 |
| 13 | Mar 28 – Apr 03 | 25.5 | 17.7 | 21.60 | 0.12 | 74 |
| 14 | Apr 04 - Apr 10 | 22.8 | 14.7 | 18.75 | 0.7 | 68 |

**SMW: Standard Meteorological Week, °C: Degree Celsius, mm: millimeters, %: percentage**

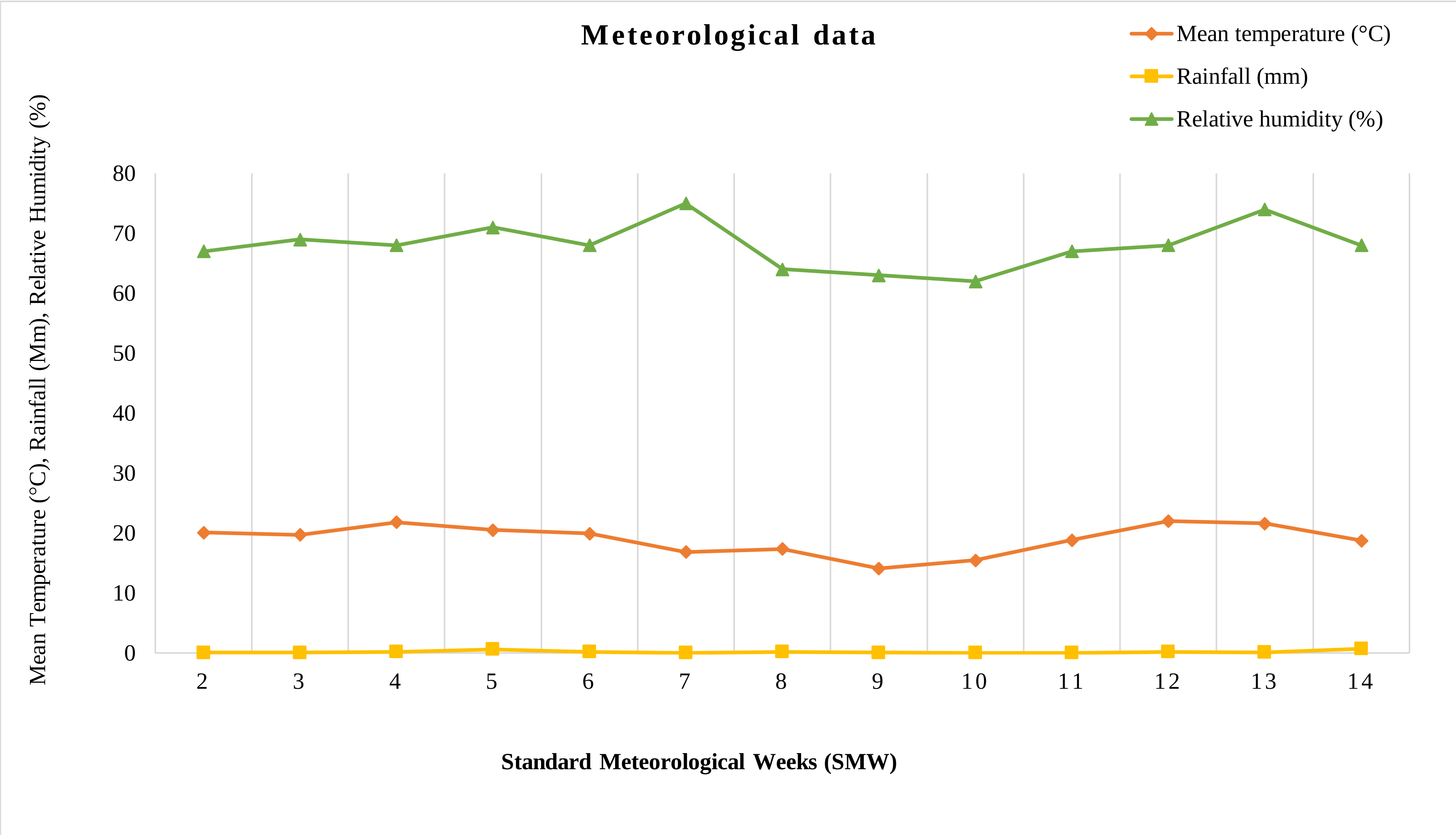


**Fig. 3.2: Metrological observation during the period of research (January 2022-April 2022)**

## 3.8 INTERCULTURE OPERATIONS

### 3.8.1 Irrigation

In the experiment, the field was irrigated to its field capacity before sowing. Such as, pre-sowing irrigation was given on 2 January 2020. Protective irrigation for sufficient soil moisture were provided immediately after sowing and then on every other morning for the next three weeks. The crop was irrigated at an interval of 3-4 days. Compost was applied at the time of sowing.

### 3.8.2 Thinning:

Plant population was maintained following thinning of plant at 30 days after sowing (DAS) and in all treatment plant population was maintained to 21 plants per $m^2$. Thus, the initial population of plants in all the sowing treatment which initially was very high was restricted to the above-mentioned values.

### 3.8.3 Hand weeding:

Timely three hand-weeding were performed at 30 DAS, 60 DAS and 90 DAS were done manually with a Khurpi to remove weeds and improve soil aeration and also to conserve soil moisture. Some major weeds during the cropping period dominating were, i.e., *Anagallis arvensis, Fumaria parviflora, Chenopodium album, Phalaris minor* etc.

### 3.8.4 Experimental and treatment details

**Table 3.2: Details of the experiment**

| | |
|---|---|
| Crop | Indian Mustard |
| Statistical design | Random Block Design |
| No. of treatment | 12 |
| Date of sowing | 9/01/22 |
| Replication | 3 |
| Spacing | 3m x 2m |
| Field size | 9.5m x 8.75m |
| Plot size | 3m x 2m |
| Experimental site | Karsingsa, Papum Pare, Arunachal Pradesh. |
| Fertilizer | Sulfur (Sulfex) |
| Seed | Local genotype (Sagalee) |

**Table 3.3: The details of treatments on mustard.**

| Treatments | Sulfex (80%) for $6m^2$ |
|---|---|
| $T_1R_1$ | 0 kg $ha^{-1}$ |
| $T_2R_1$ | 30 kg $ha^{-1}$ |
| $T_3R_1$ | 40 kg $ha^{-1}$ |
| $T_4R_1$ | 60 kg $ha^{-1}$ |
| $T_1R_2$ | 0 kg $ha^{-1}$ |
| $T_2R_2$ | 30 kg $ha^{-1}$ |
| $T_3R_2$ | 40 kg $ha^{-1}$ |
| $T_4R_2$ | 60 kg $ha^{-1}$ |
| $T_1R_3$ | 0 kg $ha^{-1}$ |
| $T_2R_3$ | 30 kg $ha^{-1}$ |
| $T_3R_3$ | 40 kg $ha^{-1}$ |
| $T3R_4$ | 60 kg $ha^{-1}$ |
| $T_1R_4$ | 0 kg $ha^{-1}$ |
| $T_2R_4$ | 30 kg $ha^{-1}$ |
| $T_3R_4$ | 40 kg $ha^{-1}$ |
| $T_4R_4$ | 60 kg $ha^{-1}$ |

## 3.9 Detail of the crop

The landrace sown was collected from Sagalee, Papum Pare, Arunachal Pradesh. Considering the nature of factors under study and the convenience of agricultural operation and efficiency, the experiment was laid out in Randomized Block Design (RBD).

### 3.9.1 Field operations

The experimental field was prepared by deep ploughing with a tractor-drawn disc plough followed by harrowing and planking so that there were no clods in the field and to get a good tilth for proper germination and establishment of the crop for achieving higher productivity. The field was subsequently cleaned by picking stubbles of previous crops followed by manual weeding. The soil was then uniformly mixed with vermicompost. After completion of field preparation, the layout was prepared. Measuring tape, rope, and bamboo sticks were used for demarcation of individual plot.

### 3.9.2 Fertilizer application

The recommended dose of sulfur was applied to the crop. Sulfur was supplied for four levels: 0, 30, 40, and 60 kg S $ha^{-1}$. Full doses of sulfex were used as basal applications according to treatment.

### 3.9.3 Varieties

Indian mustard (*Brassica juncea* L.) belonging to the family Brassicaceae was selected for the research purpose. The seed was procured from Sagalee. The seed was locally grown landrace of mustard.

### 3.9.4 Seed rate and sowing

Seeds were sown on 9 January 2022 at the rate of 5 kg $ha^{-1}$ in all the treatments. The row to row and plant-to-plant spacing was kept at 30 and 15 cm respectively between the seeds during s

owing. Seeds was sown at the depth of 3-4 cm below the soil.

## 3.10 post-sowing operation

### 3.10.1 Thinning

The plant population was maintained at one plant planted at a 15cm distance, 30 days after sowing (DAS) to obtain a uniform plant population with 21 plants in each treatment.

### 3.10.2 Hand weeding

Timely three hand-weeding were performed at 30, 60, and 90 DAS with khurpi in order to remove the weeds and improve soil aeration, and also to conserve soil moisture. Some major weeds during the cropping period dominating were, *Anagallis arvensis, Fumaria parviflora, Chenopodium album, Phalaris minor* etc.

### 3.10.3 Plant protection

A spray of Plethora 3ml per liter was sprayed using a knapsack sprayer for controlling saw-fly and dimecron @ 0.03% was applied to protect the crop from aphids.

### 3.10.4 Harvesting

The crop was harvested on 9.04.2022, as soon as 85 per cent siliqua turned yellowish brown so as to prevent the shattering. Border rows were harvested first followed by the central plots. The plant of each net plot of 3 m x 2 m was harvested separately and tied in bundles and tagged. These bundles were left on the threshing floor for sun drying. After complete drying, bundles were weighed to record seed yield and stover yield. Thereafter, threshing was done separately. Seed and stover were separated by manual winnowing and their yield per plot was recorded.

**Table 3.4: Pre sowing cultural operation**

| S. No: | Operations | Date | Method used |
|---|---|---|---|
| 1 | Ploughing | 17.12.2021 | Plough (Power tiller) |
| 2 | Harrowing | 20.12.2021 | Disc Harrow (Power tiller) |
| 3 | Planking | 21.12.2021 | Leveler (Power tiller) |
| 4 | Layout | 22.12.2021 | Manually |
| 5 | Furrow opening | 23.12.2021 | Manually with the help of furrow opener at 30 cm apart. |
| 6 | Pre irrigation | 2.01.2022 | Manually (pipe) |
| 7 | Weighing of S | 8.01.2022 | Weighing machine |
| 6 | Fertilizer application as basal | 9.01.2022 | Manually |
| 7 | Sowing | 9.01.2022 | Manually |

**Table 3.5: Post-sowing cultural operation**

| S. No: | Operations | Date | Method used |
|---|---|---|---|
| 1 | Preparation of bunds and channels. | 11.01.2022 | Manually |
| 2 | Thinning | 24.01.2022 | Manually |
| 3 | Irrigation | 10.01.2022 | Manually jerry can |
| 4 | Spraying of insecticides | 14.02.2022 | Plethora 3ml/litre was sprayed using a knapsack sprayer for controlling saw fly. |
| 5 | Harvesting | 9.04.2022 | Manually with help of sickle. |
| 6 | Threshing | 16.04.2022 | Manually after drying the plants in sun. |
| 7 | Winnowing | 16.04.2022 | Manually |

## 3.11 Observations recorded during the crop growth period

The observation was carried out for 30, 60, and 90 DAS. The following parameters were observed and recorded.

### 3.11.1 Growth parameter

#### 3.11.1.1 Plant height (cm)

Sampling was done on five plants selected from each treatment randomly by tagging them. Plant height was measured in cm with the help of a measuring tape from the base of the plant to the top height of the plant at 30, 60, and 90 DAS.

#### 3.11.1.2 Number of leaves per plant

The number of leaves was counted at 30, 60, and 90 DAS. The mean value was computed per plant.

#### 3.11.1.3Number of branches per plant

The number of branches was counted for per plant at 30, 60 and 90 DAS. The average value was computed on basis of per plant.

#### 3.11.1.4 Dry matter accumulation per plant (g/plant)

Five plants were randomly uprooted from each treatment with the help of khurpi. Samples were sun-dried thoroughly and their dry weight was recorded at different growth stages at 30, 60, and 90 DAS and expressed in gram per plant after thoroughly drying the sample till constant weight.

## 3.12 Yield parameters

### 3.12.1 Siliquae per plant

The number of siliquae per plant of each plot was counted and the average was calculated and recorded on five plants (tagged).

### 3.12.2 Seeds per siliquae

Seeds per siliqua was registered for the plant by counting the number of seeds of selected siliqua from the five tagged plants of each plot and the mean was recorded. The bundles were sun dried, weighed, threshed, and finally, seeds were cleaned and yield was recorded.

### 3.12.3 Test weight (g)

Thousand cleaned dried seeds were counted from each treatment and their weights was recorded as test weight (g).

### 3.12.4 Seed yield (q ha$^{-1}$

After threshing and winnowing, the clean seeds obtained from the produce of individual plots were weighed as seed yield per treatment and was converted into q ha$^{-1.}$

### 3.12.5 Stover yield (q ha$^{-1}$)

After threshing, the weight of stem and chaff per plot was recorded. These were converted to q ha$^{-1}$.

### 3.12.6 Harvest Index (%)

Harvest index was calculated by ratio of economic yield (seed yield) to biological yield (seed yield + stover yield), worked out to estimate the harvest index as per formula given by the formula (Donald and Hamblin, 1978).

Harvest Index (%) = Economic yield ÷ Biological yield X 100

Where,

Economic yield = seed yield (q ha$^{-1}$)

Biological yield = Seed yield (q ha$^{-1}$) + stover yield (q ha$^{-1}$)

### 3.13 Soil parameters

The soil of the experimental site was analysed for the physical-chemical properties i.e., Soil pH.

### 3.13.1 Soil pH

A glass electrode pH meter was used for measuring pH. In order to obtain the average soil sample, the soil was collected from four corners of the experiment site by using a hand trowel and dig for 5 inches below the soil surface. The collected soil sample was cleaned by removing stones, sticks, and other debris from the soil. Break the soil clumps to get a good tilth. Weigh 10 g of soil sample into a 50 ml beaker, and add 25 ml distilled water in 1:2.5 soil water suspension. Stir for 30 minutes. (Black, 1965).

## 3.14 Statistical analysis

Statistical analysis was done to identify trends and valuable insights. Information collected on growth, yield attributes, and yield on Indian mustard during the course of the investigation was subjected to Randomized Block Design (RBD) by following the standard analysis of variance technique (ANOVA) as suggested by Gomez and Gomez (1984). The significance of the difference among the treatment effect was tested through “F-test and critical difference (CD) was calculated, wherever the results were found significant. To elucidate the nature and magnitude of treatment effects, tables along with S.Ed. and CD were prepared and are given in the text of the chapter "Experimental results" and their analysis of variance in the Appendices at the end.

CD @ 5% = S.Ed. × t

S.Ed. (±)= $\sqrt{2MSe/r}$

CV= $Standard\ deviation\ \div Sample\ mean$ x 100

CD: Critical Difference

t: Tabulated value at error degree of freedom (d.f) and 0.05% level of significance.

S.Ed. (±): Standard Error of difference

MSe: Mean Sum of error

r: Replication

**ANOVA Table**

| **S.V** | **D.F** | **SS** | **MSS** | **$F_{cal}$** | **$F_{tab}$** | **NS/S** |
|---|---|---|---|---|---|---|
| **Replication** | (r-1) | RSS/d.f | | | | **NS/S** |
| **Treatment** | (t-1) | TSS/d.f | | | | **NS/S** |
| **Sulfur (a)** | (a-1) | a/d.f | | | | **NS/S** |
| **SN** | (a-1) | Sn/d.f | | | | **NS/S** |
| **Error** | (r-1)(a-1) | Error/d.f | | | | |

ANOVA Table S.V: Source of Variance, D.F: Degree of difference, SS: Sum of square, MSS: Mean sum of square, $F_{cal}$: Calculated F value, $F_{tab}$: Tabulated F value, NS: Not significant, S: Significant

Mean sum of square, $F_{cal}$: Calculated F value, $F_{tab}$: Tabulated F value, NS: Not significant, S: Significant.

## 3.15 Economic studies

### 3.15.1 Cost of cultivation (₹ $ha^{-1}$)

The cost of different operations for the applied treatment was worked out separately. The cost of cultivation was recorded on a per hectare basis. The total cost of all inputs was computed by adding all expenditures involved as per treatment on the experimental plot.

### 3.15.2Gross return (₹ $ha^{-1}$)

The gross return was calculated by considering the monetary value of the economic production of different treatments on the basis of the prevailing local market price per hectare.

Gross income (₹ $ha^{-1}$) = Sale cost of mustard seed (₹ $ha^{-1}$) + Sale cost of stover (₹ $ha^{-1}$).

### 3.15.3Net returns (₹ $ha^{-1}$)

The total cost of cultivation of mustard was subtracted from the total gross returns to work out the net returns.

Net return = Gross return (₹ $ha^{-1}$) - Total cost of cultivation (₹ $ha^{-1}$).

### 3.15.4 Benefit: Cost Ratio

To determine the viability of produce rom the experiment the benefit-cost ratio was calculated. The B:C ratio also helped in forecasting the Projects risk return profile.

Benefit: Cost Ratio value was obtained by using the formula

$$\text{Benefit: Cost Ratio} = \frac{\text{Net return (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

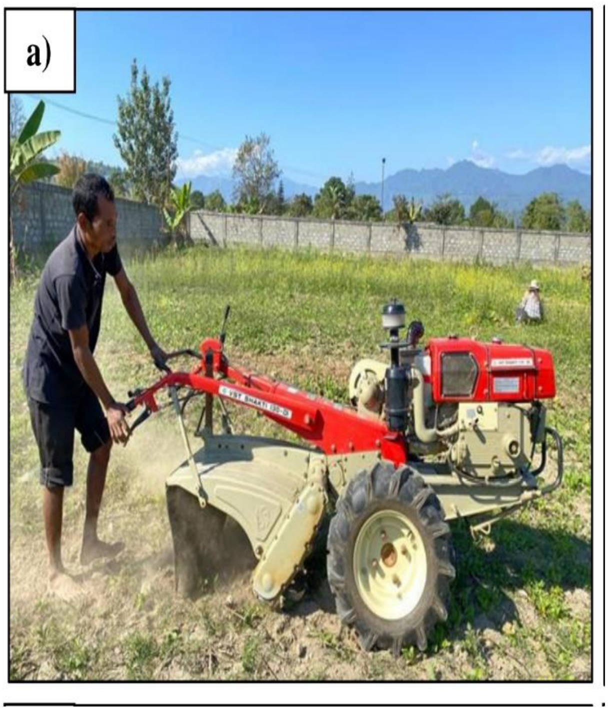


**Plate 1: Preparation of field**


Plate 2: Fertilizer used for the experiment (Sulfex)


Plate 3: Weighing of Sulfex

Plate 4: Pre sowing spacing of crop

Plate 5: Tagging

Plate 6: Layout of the field

Plate 7: 30 Days after sowing

Plate 8: 60 Days after sowing

Plate 9: 90 Days after sowing

Plate 10: Aphid infestation


Plate 11: Field inspection

Plate 12: Harvesting

**CHAPTER–IV**

# RESULTS AND DISCUSSION

The results of field studies aimed at finding suitable application of sulfur fertilizer level for mustard crop, which was obtained during the course of investigation entitled "Effect of Sulfur application on the growth and yield of mustard (*Brassica juncea* L.) in Arunachal Pradesh, India" have been presented in this chapter.

## 4.1 Effect of Sulfur application on growth and yield of mustard

### 4.1.1 Plant height (cm)

Data on plant height (cm) are presented in Table 4.1 and illustrated graphically in Fig. 4.1. From the data, it is evident that plant height at different stages was significantly affected by the application of Sulfur fertilizers over control.

Plant height during all stages of crop growth except at 30 DAS was significantly influenced by different rate of S fertilizer application. At 30 DAS, the highest plant height was found in $T_2$ (13.65 cm) and lowest in$T_3$ (9.17 cm). At 60 DAS, the highest plant height was recorded in $T_4$ (63.14 cm) and lowest in $T_3$ (58.43 cm). At 90 DAS, the highest plant height was recorded in $T_4$ (74.26 cm) and lowest in $T_3$ (45.75 cm).

Plant height increased after 30 DAS and continued up to 90 DAS. At all crop growth stages, except maturity, plant height was significantly higher when Sulfur was applied. Maximum plant height was recorded with application of 60 kg S $ha^{-1}$ (Sulfex 80% WP) over control and all other treatment combinations. This might be because of the mustard seeds having 28- 36 % protein content with a high nutritive value. This could also be due to Sulfur which has a direct effect on cell division, growth and cell elongation which resulted in increase of plant height. The reports are similar to the findings of Singh *et al*., 022.

**Table 4.1: Effect of Sulfur on plant height (cm) at 30, 60, and 90 DAS**

| Treatment | Plant height (cm) | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS |
| $T_1$ | 10.44 | 59.23 | 52.33 |
| $T_2$ | 13.65 | 61.35 | 68.55 |
| $T_3$ | 9.17 | 58.43 | 45.74 |
| $T_4$ | 12.33 | 63.14 | 74.26 |
| S.Em. ± | 0.01 | 0.01 | 0.11 |
| C.D. 5% | 0.03 | 0.04 | 0.04 |

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

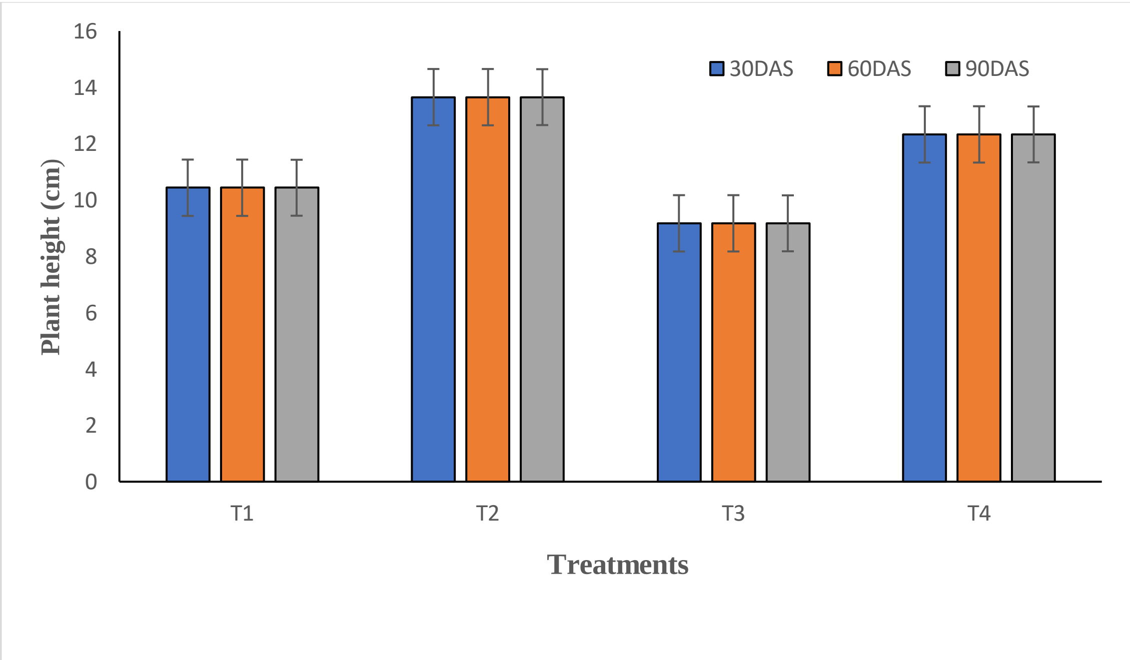


**Fig. 4.1: Effect of Sulfur on plant height at 30, 60, and 90 DAS**

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

### 4.1.2 Number of branches per plant

Number of branches per plant of mustard were significantly influenced by the level of S at 30, 60 and 90 DAS. With the increase in application of S, the number of branches per plant was observed to be significantly higher. At 30 DAS, among the different treatments, the highest number of branches per plant was found in $T_4$ (5.35) and the lowest in $T_1$ (3.42). At 60 DAS, among the different treatments maximum number of branches per plant was recorded significant in $T_4$ (18.65) and minimum was recorded significantly with $T_2$ (17.96). In 90 DAS, among the different treatments maximum number of branches per plant was recorded in $T_3$ (26.84) and minimum number of branches per plant in $T_4$ (19.53). The increase in main branches might be caused by increased cell division and differentiation with appropriate supply, as well as by higher photosynthetic availability for main shoots, as Sulfur helps in increasing the crop's photosynthetic growth.

Kumar *et al.,* (2001) reported that plant height, primary and secondary branches per plant were significantly higher with the application of 40 kg Sulfur per has compared to the control and 20 kg S $ha^{-1}$.

Maurya (1995) observed that application of S in mustard at the rate of 40 kg S $ha^{-1}$ increased the plant height and number of branches per plant.

**Table 4.2: Effect of Sulfur on number of branches per plant at 30, 60 and 90 DAS**

| Treatments | Number of branches | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS |
| $T_1$ | 3.42 | 19.53 | 22.15 |
| $T_2$ | 4.15 | 17.96 | 25.33 |
| $T_3$ | 5.25 | 18.34 | 26.84 |
| $T_4$ | 5.35 | 18.65 | 19.53 |
| S. Em. (±) | 0.01 | 0.01 | 0.01 |
| C.D. (5%) | 0.03 | 0.05 | 0.05 |

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

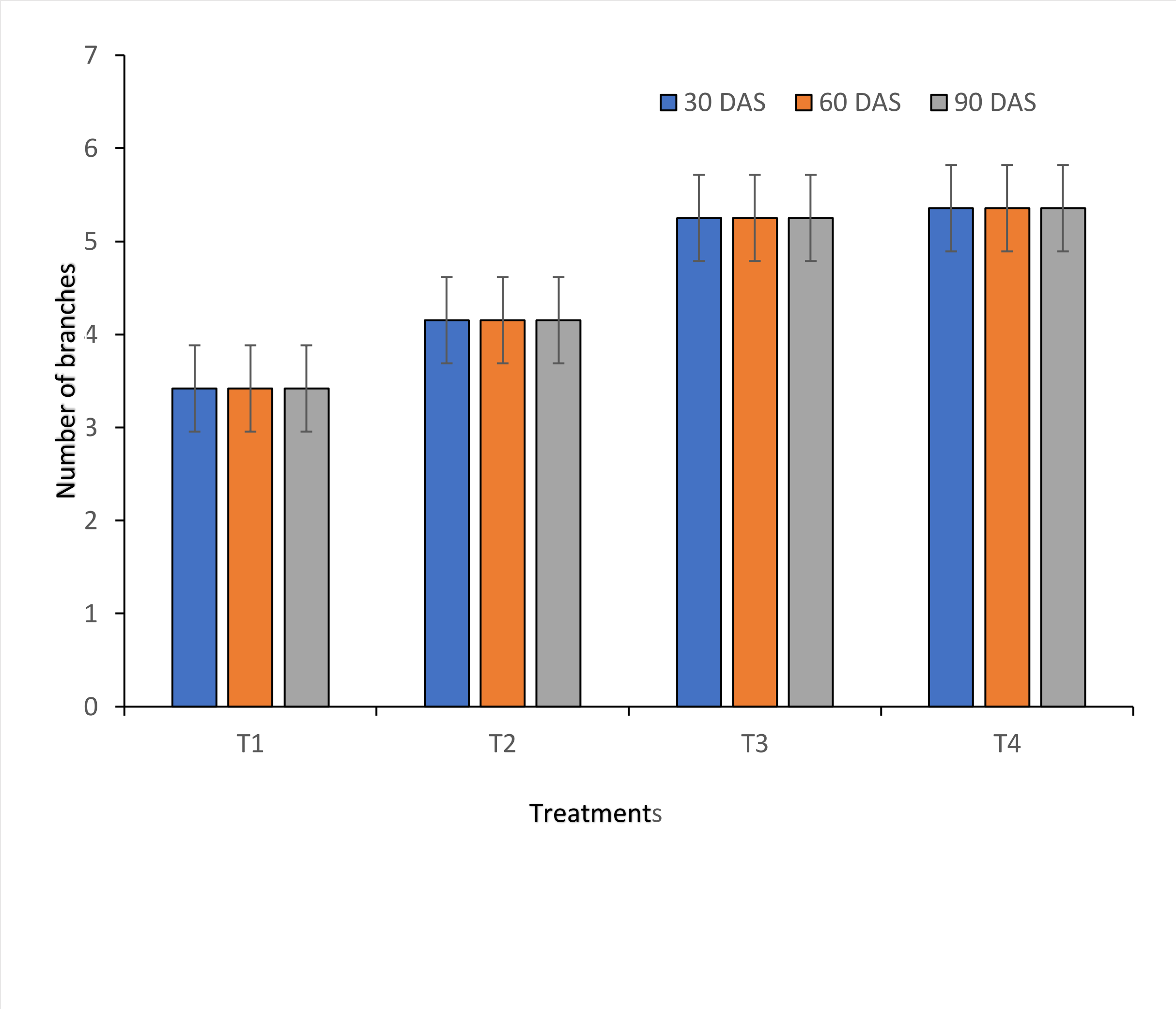


**Fig. 4.2: Effect of S on number of branches per plant at 30, 60 and 90 DAS**

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

### 4.1.3 Fresh weight (g)

With the increase in S level the fresh weight also increased gradually from 30 to 90 DAS. At 30 DAS among the different treatments the highest fresh weight was recorded in $T_4$ (3.57 g) and the lowest was found in $T_1$ (3.21 g). At 60 DAS, among the different treatments highest fresh weight per plant was recorded significantly in (22.72 g) and minimum was recorded significantly in$T_1$ (20.49 g). And at 90 DAS, among the different treatments maximum fresh weight was recorded in $T_4$ (63.94 g) and minimum fresh weight in $T_1$ (62.55 g).

S involves in the synthesis of essential amino acids, like Cysteine, Cystine and Methionine. The sulfur linkages provide the source of pungency in the oil and overall increases the growth and biomass of crop (Kumar and Yadav, 2007).

**Table 4.3: Effect of S Fresh weight (g per plant) at 30, 60, and 90 DAS**

| Treatment | 30 DAS | 60 DAS | 90 DAS |
|---|---|---|---|
| $T_1$ (control) | 3.21 | 20.49 | 62.55 |
| $T_2$ (20 kg S $ha^{-1}$) | 3.31 | 21.31 | 63.41 |
| $T_3$ (30 kg S $ha^{-1}$) | 3.42 | 22.52 | 63.82 |
| $T_4$ (60 kg S $ha^{-1}$) | 3.57 | 22.72 | 63.94 |
| S. Em. (±) | 0.01 | 0.09 | 0.11 |
| C.D. (5%) | 0.03 | 0.34 | 0.40 |

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

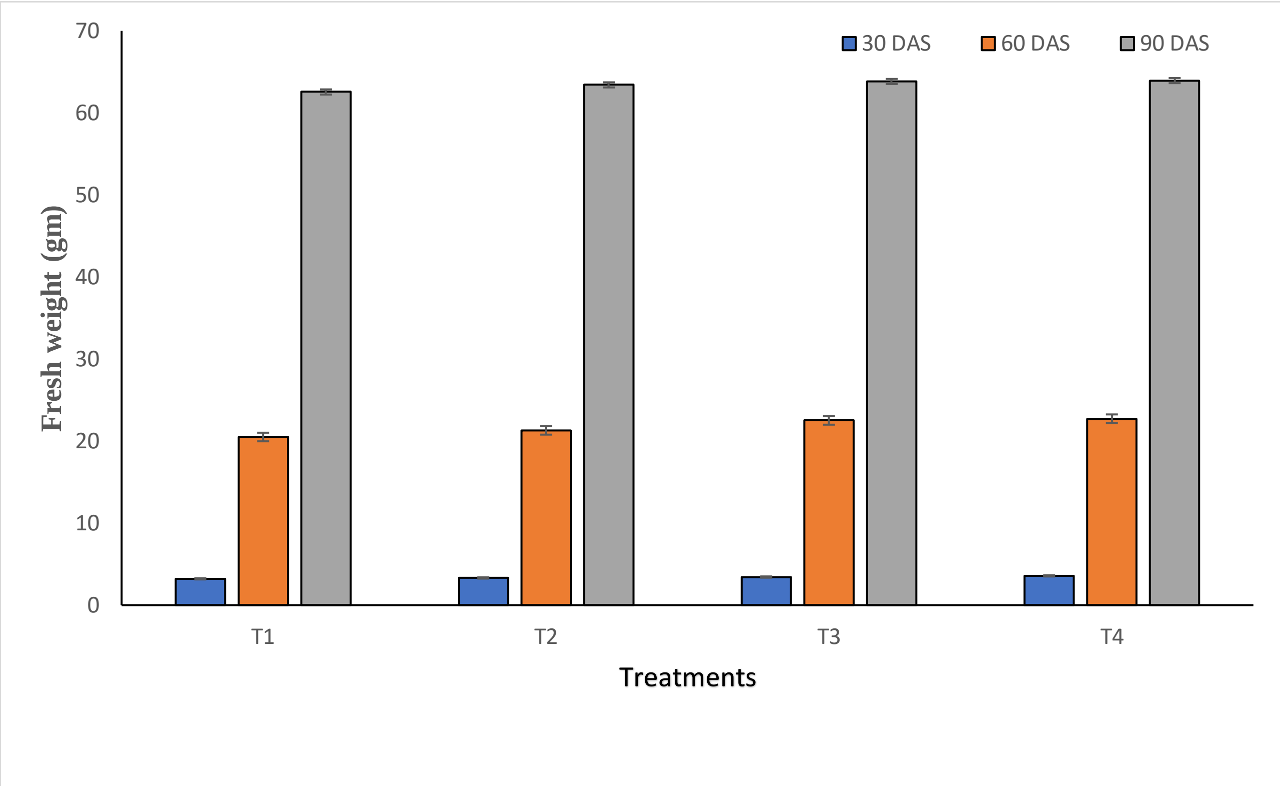


**Fig. 4.3: Effect of Sulfur on fresh weight (g) at 30, 60, and 90 DAS**

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

**4.1.4 Dry Weight (g)**

With the increase in S level the dry weight also increased gradually from 30 to 90 DAS. At 30 DAS among the different treatments highest dry weight was recorded in $T_4$ (5.35 g) and the lowest was found in $T_1$ (3.42 g). At 60 DAS, among the different treatments highest dry weight per plant was recorded significantly with $T_1$ (19.53 g) and minimum was recorded in $T_2$ (17.96 g). And at 90 DAS, among the different treatments maximum dry weight was recorded significantly in$T_3$ (26.84 g) and minimum dry weight was recorded in $T_4$ (19.53 g). The sulfur application might have led to improvement in the nutrient content in soil, which might have resulted in increased nutrient uptake and dry matter production.

Dubey and Khan (1993) reported that application of S up to 30 kg ha$^{-1}$ significantly increased the dry matter in mustard at all the crop growth stages starting from 30 DAS to harvest. Giri *et al.* (2006) reported the higher values of growth parameter of mustard with the application of 60 kg S ha$^{-1}$.

**Table 4.4: Effect of Sulfur on Dry weight (g per plant) at 30, 60, and 90 DAS**

| Treatments | 30DAS | 60DAS | 90DAS |
|---|---|---|---|
| $T_1$ | 3.42 | 19.53 | 22.15 |
| $T_2$ | 4.15 | 17.96 | 25.33 |
| $T_3$ | 5.25 | 18.34 | 26.84 |
| $T_4$ | 5.35 | 18.65 | 19.53 |
| S.Em.± | 0.01 | 0.01 | 0.01 |
| C.D.5% | 0.03 | 0.05 | 0.05 |

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

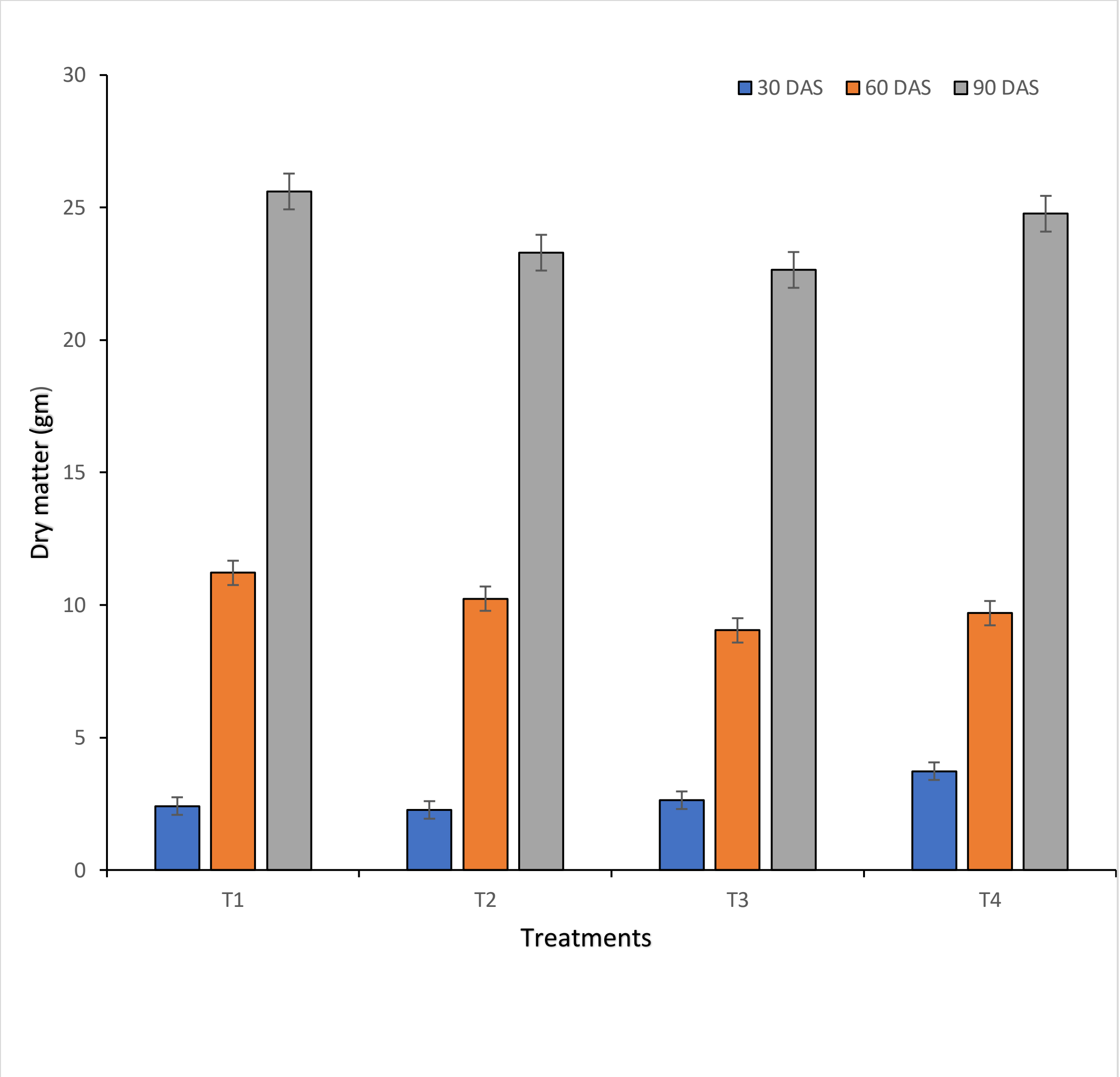


**Fig. 4.4: Effect of Sulfur on Dry weight (g per plant) at 30, 60, and 90 DAS**

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

#### 4.1.5 Number of Siliquae per plant

Highest number of siliquae per plant was recorded with the application of 60 kg S ha$^{-1}$ in $T_4$ (128.18). Minimum number of siliquae per plant was recorded in control plot, $T_1$ (121.58). These results clearly showed that mustard yield was significantly influenced by fertilizer treatments and to obtain optimum yield potential, sufficient amount of nutrient doses is required to provide a healthy plant population. It might be due to the production of more chlorophyll content, elevated photosynthetic rate and cell division, more translocation of assimilates towards reproductive parts than vegetative parts because of higher partitioning of assimilates towards sink with increased sulfur application. Application of sulfur might have enhanced the growth and ultimately contributed towards higher number of branches per plant which attributed to more siliquae per plant and thus more seeds per siliquae. The data is tabulated in Table 4.5 and presented in Fig. 4.5.

Similar result was reported by Singh and Kumar (2014) where the application of 45 kg S ha$^{-1}$ showed the highest seed yield, per plant, siliquae length, number of seed per siliquae and harvest index.

**Table 4.5: Number of siliquae per plant**

| Treatments | Siliquae per plant |
|---|---|
| $T_1$ | 121.58 |
| $T_2$ | 124.32 |
| $T_3$ | 126.28 |
| $T_4$ | 128.18 |
| S.E.m± | 0.76 |
| C.D.5% | 2.65 |

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

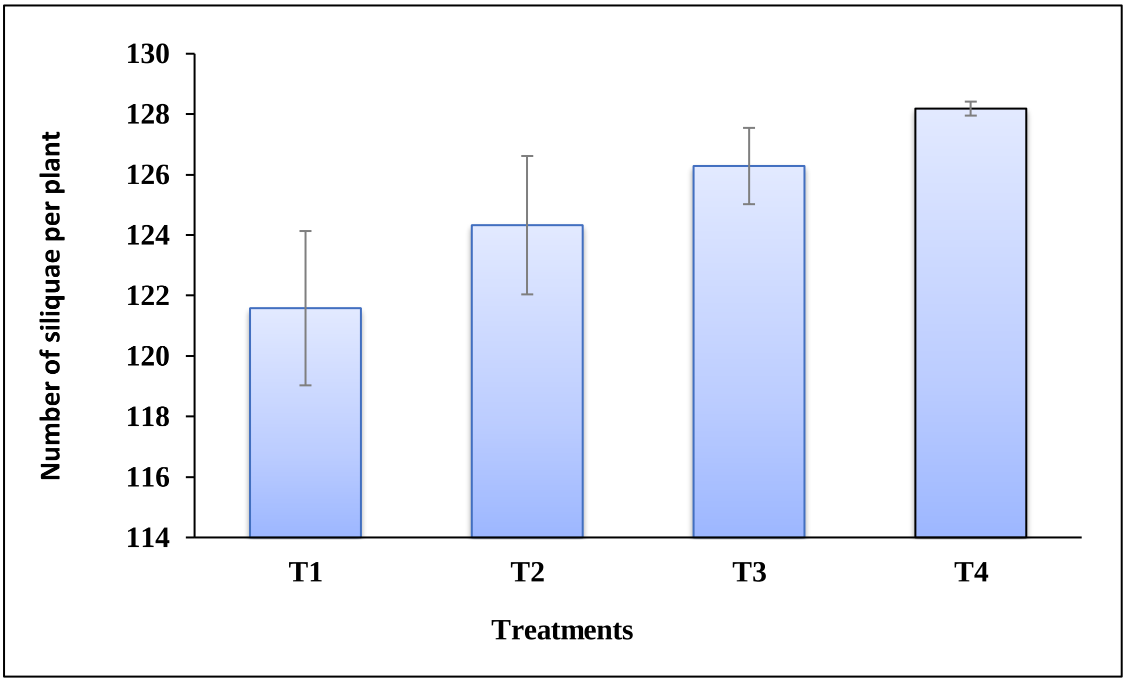


**Fig. 4.5: Effect of Sulfur on number of siliquae per plant**

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

### 4.1.6 Seed per siliquae, Stover weight and test weight

Number of Seeds per siliquae, stover weight and test weight were influenced significantly by increase in S level. The data is presented in Table 4.6 and Fig. 4.7.

Maximum number of seeds per siliquae, stover weight and test weight were recorded. Application of 60 kg S ha$^{-1}$ ($T_4$) was higher over control at all stages of plant growth. These results clearly showed that mustard yield was significantly influenced due to fertilizer treatments. The results are in accordance with Singh and Mukherjee (2004). They reported that number of siliquae per plant, number of seeds per siliquae, test weight, seed yield, stover yield and harvest index increased with increasing rates of S from the control to 45 kg S ha$^{-1}$ in mustard. Whereas Harendra *et al.* (2005) reported that the application of S up to 60 kg ha$^{-1}$ significantly increased the siliquae per plant, seeds per siliquae, 1000 seed weight, seed yield and stover yield of mustard.

**Table 4.6 Seeds per siliquae, stover weight and test weight in mustard**

| Treatment | Seeds per siliquae | Stover weight(g) | Test weight(g) |
|---|---|---|---|
| $T_1$ | 12.34 | 13.24 | 3.91 |
| $T_2$ | 12.88 | 13.49 | 4.34 |
| $T_3$ | 13.08 | 13.64 | 4.82 |
| $T_4$ | 13.94 | 13.78 | 5.13 |
| S. Em. (±) | 0.15 | 0.02 | 0.14 |
| C.D. (5%) | 0.51 | 0.08 | 0.48 |

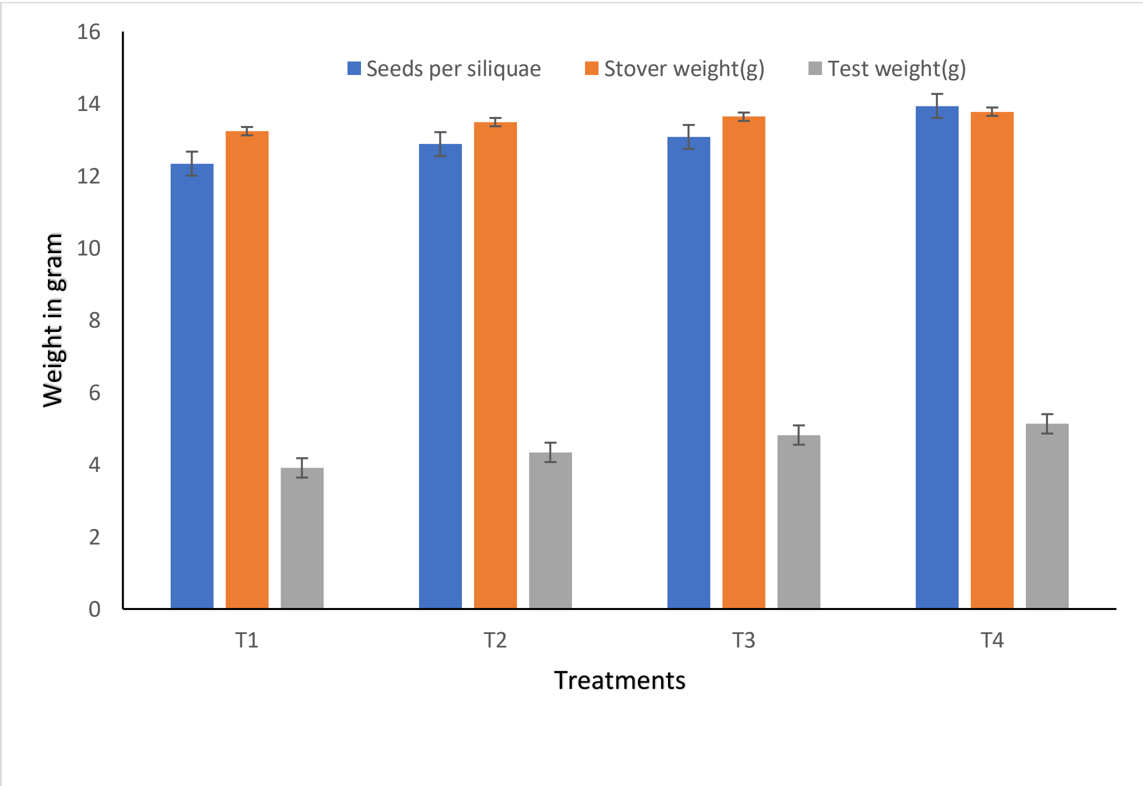


**Fig. 4.6: Seeds per siliquae, stover weight (g) and test weight (g)*$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$**

#### 4.1.7 Seed yield (q ha$^{-1}$)

Data pertaining to seed yield (q ha$^{-1}$) are provided in Table 4.7 and illustrated graphically in Fig. 4.8.

S had immense and significant influence on seed yield of mustard crop. Highest seed yield was 11.97 q ha$^{-1}$ in 90 DAS which was obtained in $T_4$ (60 kg S ha$^{-1}$) followed by the yield 11.24 q ha$^{-1}$ in $T_3$ and 10.12 q ha$^{-1}$ in $T_2$ over control at all stages of plant growth. Lowest seed yield of mustard was recorded in control (9.96 q ha$^{-1}$). The significant increment in mustard seed yield might be due to enhancement in crop growth as well as yield attributes like number of siliquae per plant, number of seeds per siliquae. Similar result was recorded by Rana *et al.* (2005) reported that the yield attributes and seed yield of mustard increased with increasing dose of S, but the increase in seed yield was significant only up to 60 kg S ha$^{-1}$.

**Table 4.7: Effect of Sulfur on Seed yield (q ha$^{-1}$) in mustard**

| Treatments | Seed yield (q ha$^{-1}$) |
|---|---|
| $T_1$ | 9.52 |
| $T_2$ | 9.78 |
| $T_3$ | 10.94 |
| $T_4$ | 11.57 |
| S. Em. (±) | 0.06 |
| C.D. (5%) | 0.22 |

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

#### 4.1.8 Stover yield (q ha$^{-1}$)

Data pertaining to stover yield (q ha$^{-1}$) are provided in Table 4.8 and illustrated graphically along with seed yield in Fig 4.8.

Varying level of S also had immense impact on stover yield. Application of 60 kg S ha$^{-1}$ ($T_4$) was observed to have maximum stover yield of (37.26 q ha$^{-1}$) which was closely followed by $T_3$ (36.28 q ha$^{-1}$) and $T_2$ (35.68 q ha$^{-1}$) over control. Minimum stover yield (34.18 q ha$^{-1}$) was reported in control treatment. This result might be attributed to higher rate of S application which might have affected the crop stover yield by boosting the vegetative growth of the crop. This result is in accordance with Jat *et al*. (2008) who reported that application of 40 kg S ha$^{-1}$ significantly increased the number of siliquae per plant, number of seeds per siliquae, test weight, seed yield and stover yield of mustard. It can be attributed to its increased biomass build-up as a result of a greater number of leaves as well as yield characteristics such as more siliquae number per plant and more seeds per siliquae. Choudhary *et al.* (2003) reported that application of S significantly increased the mustard seed and stover yield up to 60 kg S $ha^{-1}$ and the highest yield of seed and stover was obtained with 60 kg S $ha^{-1}$.

**Table 4.8: Effect of Sulfur on stover yield in mustard**

| Treatments | Stover yield (q $ha^{-1}$) |
|---|---|
| $T_1$ | 34.18 |
| $T_2$ | 35.68 |
| $T_3$ | 36.28 |
| $T_4$ | 37.26 |
| S. Em. (±) | 0.01 |
| C.D. (5%) | 0.03 |

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

#### 4.1.9 Total Yield

The total yield includes the assessment of seed yield, stover yield and biological yield (seed yield + stover yield) which is shown graphically in Fig. 4.8.

It was recorded that the growth and productivity increased with increasing level of S. The root length, shoot length, number of leaves per plant, number of branches per plant and crop growth rate were much influenced by the increase level of S. The productivity of biomass production, number of capsules, seed output, reproductive capacity and grain biological yield also increased with increasing level of S. The results are in accordance with Baudh *et al*. (2012) who found that growth and productivity increased with increasing level of S .

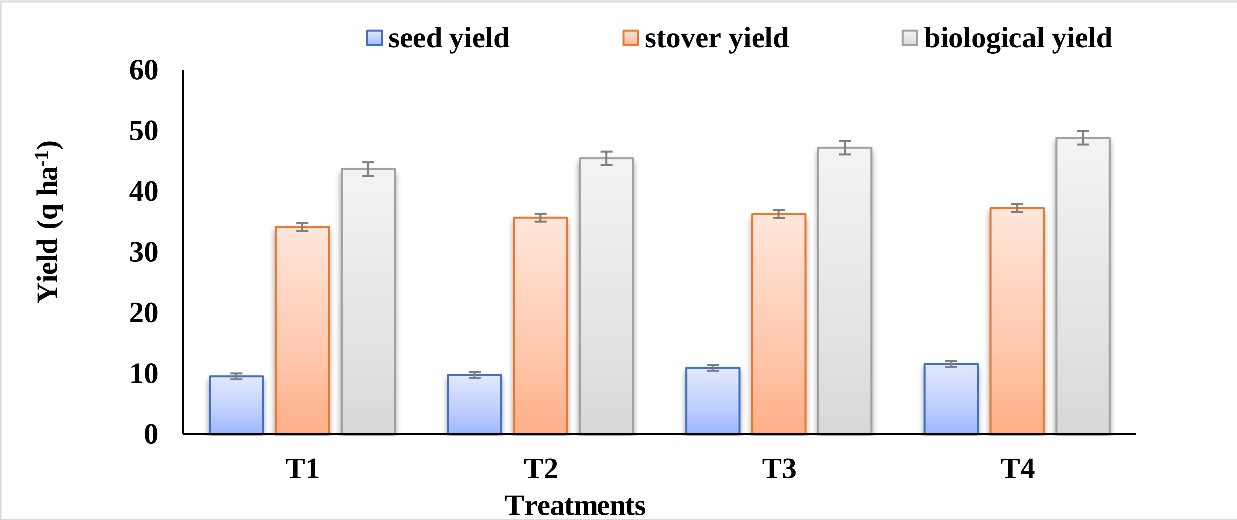


**Fig. 4.7: Effect of Sulfur on total yield in mustard**

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

**Table 4.9: Effect of S on yield parameter on mustard at harvest**

| Treatments | Siliquae per plant | Seeds per Siliquae | Test Weight | Seed Yield (q ha$^{-1}$) | Stover Yield (q ha$^{-1}$) | Harvest Index (%) |
|---|---|---|---|---|---|---|
| $T_1$ | 119.96 | 12.35 | 3.91 | 9.52 | 34.16 | 21.79 |
| $T_2$ | 122.56 | 12.88 | 4.34 | 10.12 | 35.67 | 21.51 |
| $T_3$ | 126.28 | 13.08 | 4.82 | 11.24 | 36.26 | 23.18 |
| $T_4$ | 128.33 | 13.95 | 5.24 | 11.97 | 37.27 | 23.41 |

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

### 4.1.10 Harvest index (%)

Data pertaining to Harvest index (%) are provided in Table 4.10 and illustrated graphically in Fig 4.9. Different level of S had immense effect on harvest index value of mustard crop. Maximum value of harvest index was achieved with application of 60 kg S ha$^{-1}$ ($T_4$) followed by $T_3$ and

$T_2$ over control at all stages of plant growth. Lowest harvest index value was observed in $T_1$ (0 kg S $ha^{-1}$).

**Table 4.10: Effect of Sulfur on harvest index of mustard**

| Treatments | Harvest Index (%) |
|---|---|
| $T_1$ | 21.79 |
| $T_2$ | 21.51 |
| $T_3$ | 23.18 |
| $T_4$ | 23.41 |
| S.Em. (±) | 0.17 |
| C.D. (5%) | 0.60 |

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

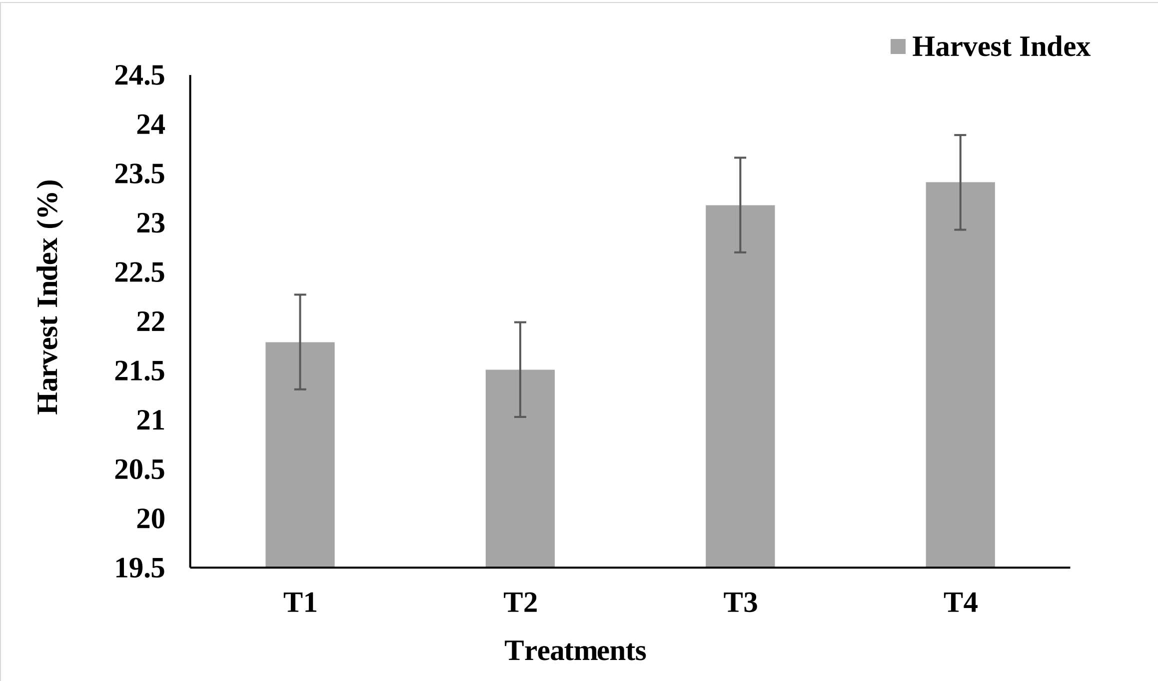


**Fig. 4.8: Effect of Sulfur on different treatments w.r.t harvest index (%) of mustard**

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

### 4.1.11 Relative Economics

It is clear from the data presented in Table 4.11 that increasing levels of S caused enhancement in the cost of cultivation and the highest value was recorded at 60 kg $ha^{-1}$ in respective of the varieties and sources of S. Increment of S level exhibited reduction of gross return. Similar trend was observed for benefit: cost ratio.

The maximum gross return and net return was observed in $T_4$ ₹83,000 and ₹43,000 with benefit cost ratio (1.3) whereas minimum mean gross income ₹45,000, net return ₹1,5000 and benefit cost ratio (0.5).

The result has been in accordance with Parihar *et al.* (2014) where he concluded that the progressive increase in levels of S from control to 40 kg $ha^{-1}$ resulted significantly 10.47 and 30.4 % higher net returns ₹25913 per ha than above levels of S.

**Table 4.11 Relative Economic on effect of Sulfur on mustard**

| Treatments | Cost of cultivation (₹) | Gross return (₹) | Net return (₹) | B:C ratio |
|---|---|---|---|---|
| $T_1$ | 30,000 | 45,000 | 15,000 | 0.5 |
| $T_2$ | 34,000 | 55,000 | 21,000 | 0.61 |
| $T_3$ | 37,000 | 62,000 | 25,000 | 0.67 |
| $T_4$ | 40,000 | 83,000 | 43,000 | 1.3 |

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

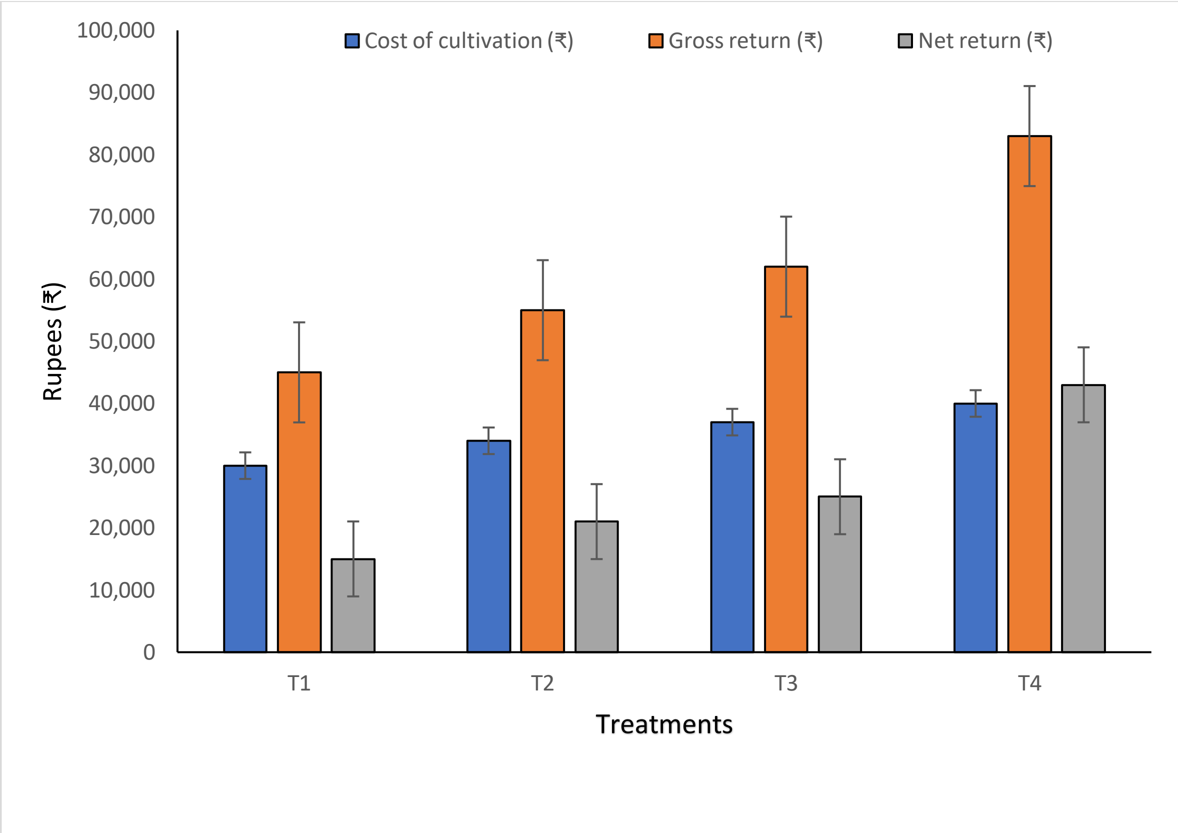


**Fig. 4.9: Graphical illustration of Relative Economics**

***$T_1$(0 kg S ha$^{-1}$), $T_2$ (20 kg S ha$^{-1}$), $T_3$ (40 kg S ha$^{-1}$), $T_4$ (60 kg S ha$^{-1}$)**

**Table 4.12 Benefit Cost Ratio of different Treatments**

| Treatments | B:C Ratio |
|---|---|
| $T_1$ | 0.5 |
| $T_2$ | 0.61 |
| $T_3$ | 0.67 |
| $T_4$ | 1.3 |

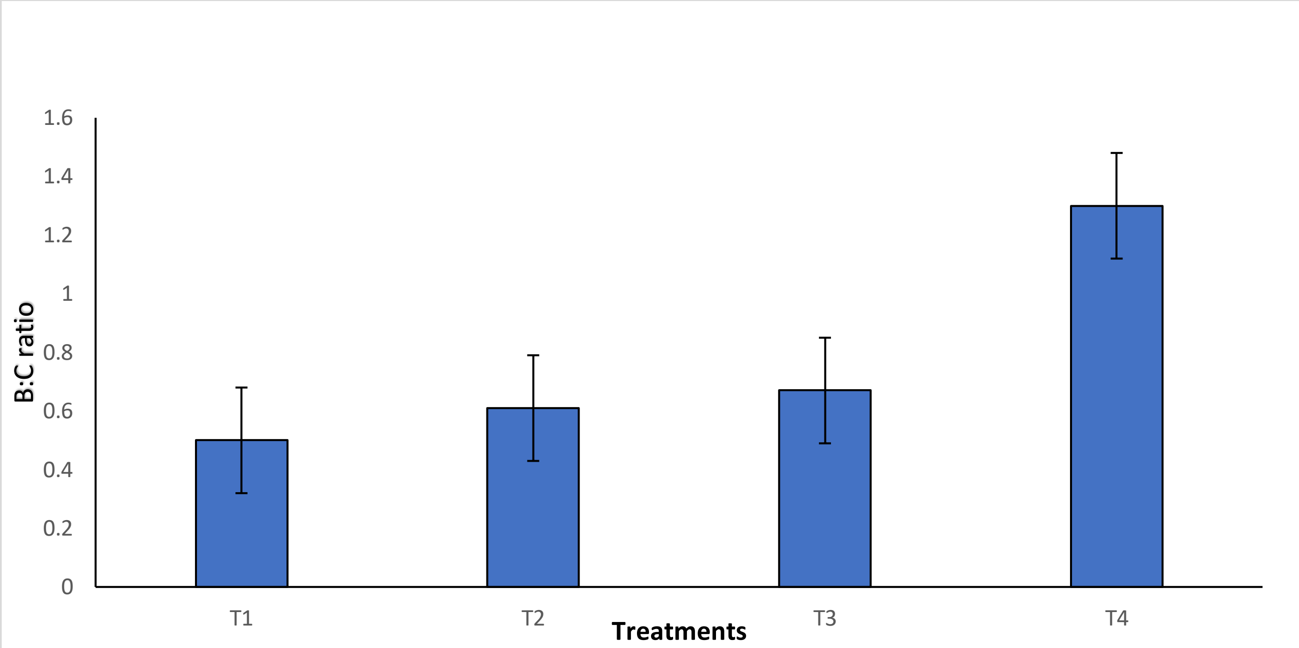


**Fig 4.10: Graphical illustration on Benefit Cost Ratio**

***$T_1$(0 kg S $ha^{-1}$), $T_2$ (20 kg S $ha^{-1}$), $T_3$ (40 kg S $ha^{-1}$), $T_4$ (60 kg S $ha^{-1}$)**

**CHAPTER–V**

**SUMMARY & CONCLUSION**

# SUMMARY

A field experiment entitled "Effect of sulfur application on the growth and yield of mustard (*Brassica juncea* L.) in Arunachal Pradesh, India "was conducted during *Rabi* season of 2022 at an Agricultural farm, Karsingsa, Papum Pare district under Rajiv Gandhi University, Rono Hills, Doimukh, Arunachal Pradesh. The experiment was laid out in Randomized Block Design with 3 replications.Treatments comprising four level of Sulfur i.e., 0,20,30 and 60 kg $ha^{-1}$. A local genotype procured from Sagalee, Papum Pare, Arunachal Pradesh was use in the experiment. The field had a sandy loamy textured soil with pH 5.8. Climate is predominated by sub-tropical climate with the humidity ranging from 60-75%. The crop was sown on the $9^{th}$of January, 2022, and harvested on April 9,2022. Spacing 15 m x 30 m, Seed rate 5 kg $ha^{-1}$, Plant population 221,326.32 plant $ha^{-1}$. Data was recorded at 30 days intervals after sowing at 30, 60, and 90 DAS, respectively. Growth and yield dry matter accumulation per plant (g), number of siliquae per plant, number of seeds per siliqua, stover weight (g), test weight (g), seed yield (q $ha^{-1}$), stover yield (q $ha^{-1}$), harvest index (%) and economics of various treatments are summarized as under.

1. Plant height increased with increasing levels of S with the advancement of crop growth stages. Plant height increased rapidly after 30 DAS and continued up to 90 DAS. At all crop growth stages except maturity, plant height was significantly higher when S was applied. Maximum plant height was recorded with the application of 60 Kg S $ha^{-1}$ (74.26 cm) over control and other treatments.
2. Number of branches per plant of mustard were significantly influenced by the level of S at 30, 60 and 90 DAS. With the increase in application of S, the number of branches per plant was observed to be significantly higher. Among the different treatments, maximum number of branches per plant was recorded significantly with $T_3$ (26.84) and minimum number of branches per plant was recorded in $T_4$ (19.53).
3. With the increase in S level the fresh weight also increased gradually from 30 to 90 DAS. At 30 DAS among the different treatments the highest fresh weight was recorded in $T_4$ (3.57 g) and the lowest was found in $T_1$ (3.21 g). At 60 DAS, among the different treatments highest fresh weight per plant was recorded significantly with $T_4$ (22.72 g) and minimum was recorded significantly with $T_1$ (20.49 g). And at 90 DAS, among the different treatments maximum fresh weight was recorded in $T_4$ (63.94 g) and minimum fresh weight in $T_1$ (62.55 g).

4. Application of S up to 60 kg $ha^{-1}$ significantly increased the dry matter in mustard at all the crop growth stages starting from 30 DAS to harvest. among the different treatments maximum dry weight was recorded significantly with $T_3$ (26.84 g) and minimum dry weight was recorded in $T_4$ (19.53 g).
5. Highest number of seeds per siliquae was recorded with the application of 60 kg S $ha^{-1}$ in $T_4$ (128.18). Minimum number of seeds per siliquae was recorded in control plot, $T_1$ (121.58). These results clearly showed that mustard yield was significantly influenced due to fertilizer treatments and to obtain optimum yield potential, sufficient nutrient doses is required to provide a healthy plant population.
6. Application of S significantly affected the yield of crop. Highest seed yield 11.97 q $ha^{-1}$reported in 90 DAS was obtained under $T_4$ (60 kg S $ha^{-1}$) followed by the yield 11.24 q $ha^{-1}$ in $T_3$ and 10.12 q $ha^{-1}$ in $T_2$ over control at all stages of plant growth.
7. Varying level of S also had immense impact on stover yield. Application of 60 kg S $ha^{-1}$ ($T_4$) was observed to have maximum stover yield of (37 q $ha^{-1}$) which was closely followed by $T_3$ (36.28 q $ha^{-1}$) and $T_2$ (35.68 q $ha^{-1}$) over control. Minimum stover yield (34.18 q $ha^{-1}$) was reported in control treatment.
8. Increment of S level exhibited increase of gross return. Similar trend was observed for benefit: cost ratio.

   The maximum gross return and net return was observed in $T_4$ ₹83,000 and ₹43,000 with benefit cost ratio (1.3) whereas minimum mean gross income ₹45,000, net return ₹1,5000 and Benefit Cost ratio (1.3).

# CONCLUSION

The study investigated the effect of Sulfur on the growth and yield of mustard in Karsingsa, Papum Pare, Arunachal Pradesh. Application of S had significant impact on growth and yield parameter. Increase in dose up to 60 kg $ha^{-1}$ resulted the ideal output. S also exhibited the economic feasibility on the basis of the net return achieved with the BC ratio (0.50). However, the results are of one season. Further experimentation is needed to have the right recommendation S levels for mustard for a particular soil and climatic situation.

On the basis of experimental findings, the following conclusion may be drawn:

1. Growth parameters like plant height, number of branches per plant, number of leaves per and dry matter production per plant is an important feature of crop management for optimizing productivity. All these agronomic characteristics increased significantly upon increasing the fertilizer dose of S up to 60 kg $ha^{-1}$.
2. Different growth parameters also influenced the yield in mustard. Yield attributing characters like number of siliquae per plant, number of seeds per siliqua, stover weight, test weight, seed yield, and stover yield complimented each other.
3. Different level of S had immense effect on harvest index value of mustard crop. Maximum value of harvest index was achieved with application of 60 kg S $ha^{-1}$ ($T_4$).
4. Among different level of S treatment (0,20,40,60 kg $ha^{-1}$) the recommended dose for the maximum output was observed in $T_4$(60 kg $ha^{-1}$).
5. Increment of S doses by 20 kg $ha^{-1}$ up to 60 kg $ha^{-1}$ ($T_4$) evenly affected the net return with maximum net return in $T_4$(₹25,000).

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# APPENDIX

Table. 1 Production cost for French bean grown under timely and late sown conditions.

| 2021-22 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | | | | $T_2$ | | | | $T_3$ | | | | $T_4$ | | | |
| **Particulars** | **Unit** | **Rate (rs)** | **Unit** | **Cost** | **Unit** | **Rate (rs)** | **Unit** | **Cost** | **Unit** | **Rate (rs)** | **Unit** | **Cost** | **Unit** | **Rate (rs)** | **Unit** | **Cost** |
| Ploughing | 1 | 1200 | 4 | 4800 | 1 | 1200 | 4 | 4800 | 1 | 1200 | 4 | 4800 | 1 | 1200 | 4 | 4800 |
| Harrowing | 1 | 900 | 4 | 3600 | 1 | 900 | 4 | 3600 | 1 | 900 | 4 | 3600 | 1 | 900 | 4 | 3600 |
| Seed (kg) | 2 | 30 | 2 | 60 | 2 | 30 | 2 | 60 | 2 | 30 | 2 | 60 | 2 | 30 | 2 | 60 |
| Seed sowing | 1 | 500 | 2 | 1000 | 1 | 500 | 2 | 1000 | 1 | 500 | 2 | 1000 | 1 | 500 | 2 | 1000 |
| Fertilizer (SSP) | - | - | - | - | 1 | 30 | 5 | 150 | 1 | 30 | 10 | 300 | 1 | 30 | 15 | 450 |
| Fertilizer application | - | - | - | - | 1 | 500 | 3 | 1500 | 1 | 500 | 4 | 2000 | 1 | 500 | 4 | 2000 |
| Hand weeding | 1 | 500 | 6 | 3000 | 1 | 500 | 8 | 4000 | 1 | 500 | 6 | 3000 | 1 | 500 | 6 | 3000 |
| Irrigation | 1 | 500 | 6 | 3000 | 1 | 500 | 6 | 3000 | 1 | 500 | 6 | 3000 | 1 | 500 | 6 | 3000 |
| irrigation equipment | 1 | 1500 | 1 | 1500 | 1 | 1500 | 1 | 1500 | 1 | 1500 | 1 | 1500 | 1 | 1500 | 1 | 1500 |
| Pesticides application | 1 | 550 | 2 | 1100 | 1 | 1500 | 2 | 3000 | 1 | 550 | 3 | 1650 | 1 | 550 | 2 | 1100 |
| Harvest | | | | | | | | | | | | | 1 | 500 | 4 | 2000 |
| Electric connection (month) | 1 | 1500 | 5 | 7500 | 1 | 1500 | 5 | 7500 | 1 | 1500 | 5 | 7500 | 1 | 1500 | 5 | 7500 |
| Miscellaneous | | | | 5440 | | | | 8400 | | | | 8590 | | | | 11,590 |
| **Total** | | | | **30,000** | | | | **34,000** | | | | **37,000** | | | | **40,000** |