SYSTEMS OF MUSTARD INTENSIFICATION AS INFLUENCED BY VARIETY AND SULPHUR

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CERTIFICATE

*This is to certify that the thesis entitled, "**SYSTEMS OF MUSTARD INTENSIFICATION AS INFLUENCED BY VARIETY AND SULPHUR**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **RUBEL ALI,** Registration no.**19-10193 under** my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date:

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Dedicated to
My
Beloved Parents

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SYSTEMS OF MUSTARD INTENSIFICATION AS INFLUENCED BY VARIETY AND SULPHUR

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm SAU, Dhaka to study the systems of mustard intensification as influenced by variety and sulphur, during the period from October 2020 to February 2021 in *Rabi* season. The experiment was consisted of two factors and followed by randomized complete block design with three replications. Factor A: Mustard varieties (3) *viz;* V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 and V_3 = BARI Sarisha-15, and Factor B: Different doses of sulphur (4) *viz;* S_0 = Control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS). Experimental result revealed that in case of different mustard varieties the lowest seed yield (1.36 t ha^{-1}) was obtained from V_1 treatment (BARI Sarisha-9). Whereas cultivating of BARI Sarisha-15 (V_3) variety gave the highest number of siliqua $plant^{-1}$ (107.11), length of siliqua (10.08 cm), number of seeds $siliqua^{-1}$ (31.40), 1000-seed weight (3.49 g), seed yield (1.99 t ha^{-1}), stover yield (4.1399 t ha^{-1}), biological yield (6.12 t ha^{-1}) and harvest index (32.18 %). In case of different doses of sulphur application the seed yield ranges between (1.27 -2.11 tha^{-1}). The highest seed yield (2.11 t ha^{-1}) was recorded in S_3 (25 % more than recommended dose of sulphur fertilizer) treatment which was due to enhanced yield attributes like siliqua $plant^{-1}$ (99.11), length of siliqua (9.52 cm), number of seeds $siliqua^{-1}$ (34.21) and 1000-seed weight (3.52 g).In case of combination treatment, cultivation of BARI Sarisha-15 (V_3) along with 25 % more than recommended dose of sulphur fertilizer (S_3) affected plant growth and yield-contributing characteristics, leading to the maximum seed yield (2.38 t ha^{-1}) than compared to other treatment combination. However, V_2S_3 (2.24 t ha^{-1}), V_3S_2 (2.37 t ha^{-1}) and V_3S_3 (2.38 t ha^{-1}) showed statistically similar seed yield ha^{-1}. As a result, it was proposed that cultivating BARI Sarisha-15 in conjunction with the recommended dose of sulphur fertilizer (V_3S_2) would help to influence plant growth and increase its ability to enhance better mustard yield production using the SMI technique.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotech.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Entomology	Entom.
Environment	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Mustard is one of the most vital oil seed crop next to soybean throughout the world (FAO, 2022). Among the oil seed crops grown in Bangladesh, mustard is considered as the principal oil seed crop which belongs to the genus *Brassica* of the family Cruciferae (Sarker *et al*.,2021). It is well adapted to all agro-climatic zones of the country and is grown in Rabi season (November-March). Mustard seeds have high energy content, having 28–32% oil with relatively high protein content (28–36%) by weight, although these values can vary slightly between varieties, growing regions and crop years. Actually mustard is covering above 69.94% of the oil cropped area and producing 38.80% of the total oil seed production in Bangladesh (Lietzow, 2021). Total area coverage and production of mustard in Bangladesh is 329671.47 ha and 396594.28 tons, respectively and rank first among the oil seed crops grown (BBS, 2021). The per capita consumption of edible oil in Bangladesh is 10-12 g day^{-1}. The internal production of edible oil only meet less than one-third of the annual requirement. The major reasons for low yield of mustard in Bangladesh are lack of high yielding variety, appropriate population density and inadequate knowledge of sowing time, sowing methods and proper management practices (Zhou*et al*., 2020). There is a great scope of increasing yield of mustard by selecting appropriate high yielding varieties, soil topography, weather condition with improved management practices (Rahman*et al*., 2022).

The system of mustard intensification is a new approach for enhancement of oilseed production over the conventional planting system. Though the optimum time of sowing of the oilseed *Brassica* is the first fortnight of October in Northern Asia but sowing of these crops get delayed to November– the first week of December owing to the delayed harvest of *kharif* crops particularly rice, soybean and cotton, due to which productivity declines. In order to accommodate multiple cropping systems on scarcely available land, transplanting of seedlings rather than direct seeding of rapeseed-mustard should be practiced. Root intensification by transplanting the seedlings could offer such an option to boost the seedling growth and yield, which is already being practiced by raising a nursery in a seed-bed or trays or polythene bags in some irrigated rapeseed-mustard growing regions in the country like Umaria and Sehore districts of Madhya Pradesh, but needs to be optimized further (Chaudhary *et al*., 2016).

Aside from modifying seedling growth, seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (Das*et al*., 2020). Rahman*et al*. (2019) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species. *Brassica* (genus of mustard) has three species that produce edible oil, they are *B. napus, B. campestris* and *B. juncea*. Of these, *B. napus* and *B. campestris* are of the greatest importance in the world's oil seed trade. In this subcontinent, *B. juncea* is also an important oil seed crop. Until recently, mustard varieties such as Tori-7, Sampad (both *B. campestris*) and Doulat (*B. juncea*) were mainly grown in this country. Recently several varieties of high yielding potential characteristics have been developed by BARI for improved production of mustard in Bangladesh (Ahmed and Kashem, 2017).

Crop yield reductions are strongly related with soil quality degradation, particularly nutrient depletions which can be attributed to either insufficient fertilizer use or imbalanced fertilization (Singh, 2018). Fertilizers have effect on yield and yield attributes of crops and justified fertilizers and resource use are crucial to maintain productivity of crops (Sultana *et al.,* 2019). Intensive cropping coupled with cultivation of high yielding varieties has extensively exhausted soil fertility not only in respect of macronutrients but also micronutrients.

Sulphur is a secondary plant nutrient, and it is important element for oilseed crops. Because it is directly involved in synthesis of sulphur containing amino acids like methionine (21% S), cystine (27% S) and cysteine (26% S). It played vital role in oil formation in oilseed crops. Sulphur is absorbed by the plant in the form of sulphate ions (SO_4^{2-}) (Shiva*et al*., 2021). Sulphur is involved in formation of chlorophyll and activation of the enzyme sulphydryl (SH^-). Mustard oil has pungency due to presence of sulphur compound glucosinolates and glucosides. Sulphur application significantly influenced the seed and stover yield of mustard (Yadav*et al*., 2022).

Sulphur concentration in healthy plants ranges from 0.1% to 0.4%. Sulphur and nitrogen are component of protein therefore; deficiency symptoms of plants are similar and appeared as yellowing leaves. However, sulphur is less mobile in plant, its deficiency symptom first appears on younger leaves and N deficiency first appears on lower leaves (Rakesh*et al*., 2021). In rapeseed and mustard sulphur deficient plant become pale and chlorotic appearance under severe condition. In most other crops

interveinal yellowing of young leaves is observed. The critical level of S for severe deficiency in leaves is 0.15% while the sufficiency level is 0.45% on dry matter basis (Shresthaet *al*., 2020).

Sulphur requirement is the highest for oilseed crop followed by pulses and least for cereals. As a thumb rule,grain can be taken as 3-4 (range 1-6) kg for cereals, 8 kg (range 5-13) for pulse and 12 kg (range 5-20) for oilseed crops (Hemesh, 2020). Further percentage of S absorbed by the plant that moves into grain is the highest for rapeseed and mustard (17-20%) as compared to 11.7% in sesamum and 8.7% in soybean and 8.5-8.7% in chickpea and black gram (Rakes*et al*., 2016).

Optimum fertilization especially with sulphur determines yield, quality and resistance in mustard due to multi-functional behavior of sulphur in synthesis of chlorophyll, seed protein, enzymatic complexes and vitamin components which is necessary for superior nutritional and market quality oilseed production. A yield enhancement of about 50 per cent in mustard crop can be received due to sulphur application under irrigated condition (Rakesh and Ganesh, 2016). However, indiscriminate use of high analysis fertilizer with low or no sulphur has made deficiency of sulphur more prominent in Bangladesh soils.

By considering the above facts the proposed research work was undertaken to achieve the following objectives:

i. To evaluate performance of different mustard varieties under SMI technique
ii. To study the effect of different doses of sulphur on growth and yield attributing characters and yield of mustard under SMI technique
iii. To determine the combined effect of variety and different doses of sulphur on growth and yield of mustard under SMI technique

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to investigate the systems of mustard intensification influenced by variety and sulphur, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of variety

Mashfiqur *et al.* (2022) conducted a study to determine salt tolerant varieties for maximizing mustard yield, as well as farmers' income. Experimental result revealed that the yields range of the varieties was 1.13 to 2.09 t ha^{-1} and oil was 41.37 to 43.40%. Variety BARI Sarisha-18 (Canola) produced the maximum yield (2.09 t ha^{-1}) followed by BARI Sarisha-16 (1.98 t ha^{-1}) and BARI Sarisha-11 (1.84 t ha^{-1}). Because BARI Sarisha-18 (Canola) and BARI Sarisha-16 are suitable for coastal areas, combining this variety with a coastal area cropping pattern will increase cropping intensity, which will benefit farmers both economically and nutritionally.

Sarker *et al*. (2021) conducted an experiment at the experimental field of Agro technology Discipline, Khulna University, Khulna during Rabi season 2016-17 to investigate the growth and yield performance of mustard varieties. The experiment was arranged in a randomized complete block design consisting of eight mustard varieties (viz. BARI Sarisha-8, BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16, Rai and Tori-7) as treatment and replicated thrice. All the growth, yield attributes and yield were substantially influence among the mustard varieties except the phenological parameters. Results of the experiment showed that the highest plant height (131.33 cm), seed yield (1813.33 kg ha^{-1}) and stover yield (3876.67 kg ha^{-1}) were found in BARI Sarisha-16. BARI Sarisha-11 was found better in respect of maximum siliqua $plant^{-1}$, weight of seeds $plant^{-1}$, 1000-seed weight and harvest index. Besides this, BARI Sarisha-14 showed the maximum number of seeds $siliqua^{-1}$.

Thakur *et al.* (2021) indicated that harvest index was significantly influenced by different varieties and maximum harvest index (36.95) was observed in T2 [genotype 45S35]. However, treatment T1 [BULLET] was found to be statistically at par with T2 [45S35].

As discussed earlier, the different hybrids have different yield potential, which is the reason for yield variation among different varieties.

Tripathi *et al*. (2021) at Kanpur (Uttar Pradesh), conducted a field experiment to determine the effect of sowing dates on growth and yield of Indian mustard. The experimental result revealed that the yield attributes *viz*., number of seeds siliqua^{-1}, number of siliqua plant^{-1}, seed yield and siliqua length were significantly influenced due to varieties and variety Varuna recorded significantly higher yield attributes than Narendra Rai and Kranti. Test weight of mustard was influenced due to genotypes and variety Varuna observed statistically maximum test weight.

Lal *et al.* (2020) from Bikaner conducted an experiment with four mustard varieties (RGN-73, RGN-229, RH-30 and Pusa bold) under late sown conditions and reported that variety Pusa bold gave significantly higher plant height and test weight than other varieties whereas, RGN-73 gave significantly higher siliquae per plant (170.1) seed yield (1231 kg ha^{-1}), stover yield (4597 kg ha^{-1}) and biological yield (5828 kg ha^{-1}) than other varieties.

Priyanka *et al.* (2020) from Hisar conducted an experiment to study the performance of different mustard varieties (Kranti, Giriraj, CS-54 and CS-58). The results revealed that maximum seed and stover yield were observed in variety CS-58 (21.84 and 78.41 q ha^{-1}) than other varieties in comparison.

Biswas *et al.* (2019) conducted an experiment at Sher-e-Bangla Agricultural University farm to evaluate the performance of five rapeseed and mustard varieties under two different planting techniques and founded that mustard varieties significantly affect seed yield. Among different varieties higher seed yield (2.24 t ha^{-1}) was observed in Improved Tori-7 variety which was followed by BARI Sarisha-16 (1.96 t ha^{-1}) and BARI Sarisha-13 (1.57 t ha^{-1}). The lowest seed yield (1.34 t ha^{-1}) was obtained from V_3 (BARI Sarisha-15) which was statistically similar with SAU SR-3 (1.53 t ha^{-1}).

Das *et al.* (2019). reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical make up.

Richa *et al.* (2019) in Rewa (Madhya Pradesh), reported that genotype of mustard crop Swarna Jyoti resulted in significantly higher oil content in seed (41.56%), oil yield (654.1 kg ha^{-1}), protein content in seed (19.01%) and protein yield (294.4 kg ha^{-1}) etc. The best genotypes were JTC1 and Pusa Jai Kisan, respectively with respect to nutritional quality of seed. Pusa Agrani recorded the lowest oil content (38.98 %), oil yield (393.0 kg ha^{-1}) and protein yield (170 kg ha^{-1}).

Meena *et al.* (2017) noted that mustard cv. Laxmi and Pusa Agrani recorded significantly higher seed yield (1544 and 1575 kg ha^{-1}), stover yield (5117 and 5142 kg ha^{-1}) and found at par with mustard cv. Bio-902, seed yield (1646 kg ha^{-1}), stover yield (5224 kg ha^{-1}).

Sodani *et al.* (2017) observed that seed/siliqua were observed at after harvesting stage under both control and drought conditions. The highest no of seed/siliqua were observed in RH-0749 16.3 (control) and RGN-48 (13.75) under drought, while lowest in Geeta 12.7 (control) and NRCHB-101 10.33 (Drought). Under drought condition percent reduction was highest in RH-0749 38.72 % and lowest in RB-50 1.88%. They also reported that highest HI was observed in RH-0749 32.03% (control) and RGN-48 (28.47%) under drought, while lowest in GEETA 26.68% (control) and NHCHB-101 25.68% (Drought). Under drought condition per cent reduction was highest in NHCHB-101 18.54 % and lowest in RH-819 0.17%.

Helal *et al.* (2016) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

Dinda *et al.* (2015) from Mohanpur conducted a study on the performance of different mustard varieties (NRCHB 101, NPJ-112, JD-6 and SEJ-2) under late sown conditions and reported that NRCHB 101 achieved significantly higher seed yield (1.54 t ha^{-1}) than other mustard varieties viz. NPJ-112, JD-6 and SEJ-2 in comparison.

Nirmal *et al*. (2015) conducted an experiment in sandy loam soil of West Bengal on two varieties of rapeseed (NC-1, B-9) and four varieties of mustard (SEJ-2, NPJ-112, JD-6 and NRCHB 101) and reported that mustard variety JD-6 recorded significantly higher plant height (180.32 cm) andwas on par with NRCHB 101 (178.03 cm).

NRCHB-101 achieved maximum number of siliqua per plant (146.10) and seed yield (1.54 t ha^{-1})

Pandey *et al.* (2015*)* at Faizabad (U.P.) reported that primary branches and secondary branches were significantly superior in *cv*. Narendra Rye-8501 over *cvs*. Rohini and NRC-HB 101 under plant geometry of 45 x 15 cm at all growth stages.

Patel *et al.* (2015) at Tikamgarh (M.P.) observed that mustard variety Pusa Bold led to record higher total dry biomass and its partitioning at all growth stages followed by *cvs*. Varuna and Pusa Agrani.

Sabia *et al.* (2015) in a field experiment in Kashmir valley reported that early planting on 1st October produced more number of siliquae (367.6 $plant^{-1}$), number of seed (21. 4 $siliqua^{-1}$) and 1000-seed weight (2.27 g) as compared to 15th October and 30th October sowings. They also reported significantly higher seed yield (17.7 q ha^{-1}), stover yield (56.7 q ha^{-1}) and biological yield (74.5 q ha^{-1}) as compared to 15th October (13.6, 39.9 and 53.7 q ha^{-1}, respectively) and 30th October (6.60, 20.9 and 27.5 q ha^{-1}, respectively) sowings.

Alam *et al.* (2014) conducted a field experiment to determine the changes in crop phenology, growth and yield of mustard genotypes under late sown condition when the crop faced high temperature. Experimental result revealed that Varieties/genotypes of mustard used in the experiment exerted significant influence on yield and yield attributes and among different varieties maximum number of siliquae/plant (108 and 90) was recorded in BJDH -05 which differed significantly from other varieties. This has contributed to higher yield. The lowest number of siliquae/plant (52.0 and 56.3) were found in BARI Sarisha-14.

Somondal *et al.* (2014) from Mohanpur conducted an experiment to study the performance of different mustard varieties (NRCHB 101, SEJ-2, Ashirwad, NPJ-112, JD-6, K-6 and B-9 as a control). The results revealed that significantly higher seed yield was observed in K-6 (1566 and 1633 kg ha^{-1}) in first and second year, respectively than other varieties in comparison.

Junjariya (2014) reported that seed yield of Indian mustard was influenced significantly with different cultivars. Bio-902 remained at par with RGN-13 and significantly superior as compared to RGN-48 and PBR-357. Bio-902 cultivar produced 8.72 and

23.03 per cent higher yield, respectively, over RGN- 48 and PBR-357. However, RGN-13 and RGN-48 were remained at par with each other and significantly superior over PBR-357.

Mamun *et al.* (2014) carried out a study on the performance of rapeseed and mustard varieties grown under different planting density and observed that BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15. They also reported that BARI Sarisha-13 mustard variety performed well in terms of 1000 seed weight (4.0 g) over rest of varieties.

Sharma (2013) from Morena conducted an experiment to study the performance of different mustard varieties (Varuna, Kranti, Rohini, JM-1 and JM-2) and reported that Rohini resulted in significantly higher seed and stover yield (2465 and 5350 kg ha^{-1}) than other varieties in comparison.

Tyeb *et al.* (2013) reported that the variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the cultivars.

Jha *et al.* (2012) at IARI, New Delhi observed that mustard *cv*. Pusa Jagannath exhibited significantly higher total dry biomass production (647 g m^2) as compared to *cv*. Pusa Agrani (450 g m^2).

Kumari *et al*. (2012) observed that mustard hybrid DMH-1 recorded significantly greater plant height (212 cm) over *cv*. Kranti (203 cm) and hybrid NRCHB-506 (196 cm).

Adak *et al*. (2011) observed significantly higher seed yield in mustard genotype BIO169-96 (3.32 t ha^{-1}) over the genotype Pusa Jai kisan (3.12 t ha^{-1}).

Afroz *et al*. (2011) observed that *cv*. BARI Sarisha-6 exhibited significantly higher plant height (96.7 cm) as compared to *cv*. BARI Sarisha-9 (84.9 cm). They also reported significantly higher seed yield was found in *cv*. BARI Sarisha-9 (1.54 t ha^{-1}) as compared to *cv*. BARI Sarisha-6 (1.41 t ha^{-1}).

Lallu *et al.* (2010) at Kanpur (U.P) observed that among different mustard genotypes, plant height of genotype RGN-152 was significantly greater (184.7 cm) as compared to

other genotypes in normal sowing and in late sown condition cv. RGN- 145 exhibited significantly greater (118.5 cm) plant height.

Rashid *et al.* (2010) conducted a field experiment to find out the effect of the different levels of fertilizers on the growth parameters of mustard varieties of BARI sharisa-9 (V_1), BARI sharisa-12 (V_2) and BARI sharisa-15 (V_3), and to find out the optimum and economically viable fertilizer dose and reported that variety BARI sharisa-15 is of the tall plant type and that others are of intermediate and short stature in plant height. The significant difference in plant height might be associated with the variety characteristics or genetic makeup of the plant.

Singh *et al*. (2010) conducted an experiment in sandy loam soils of Varanasi and reported that 'NRCHB-101' being at par to Ashirwad produced significantly higher seed yield and Stover yield over Varuna, Kranti and Vardan in both the years (1,811 kg $ha^{-1}$and 1,827 kg ha^{-1}). On pooled basis, NRCHB-101 recorded seed yield of 1,819 kg ha^{-1}, which in turn recorded 3.72, 6.33, 7.23 and 7.92 per cent higher seed yield than Ashirwad, Varuna, Kranti and Vardan, respectively.

Sultana *et al.* (2009) studied that stover yield for different varieties of rapeseed under study differed significantly. Kollania produced higher stover yield (2159.0 kg ha^{-1}) which was statistically at par with SAU Sarisha-1 (2156.0 kg ha^{-1}) and higher than Improved Tori -7 (1681.0 kg ha^{-1}).

Sana *et al.* (2003) reported that, higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

Singh *et al.* (2002) observed that biological yield was significantly higher in mustard *cv.* Laxmi (1370 kg ha^{-1}) over *cv.* BJH-1 (1190 kg ha^{-1}).

2.2 Effect of sulphur

At Mymensingh, Awal *et al.* (2020) assessed the effect of agronomic biofortification of sulphur and boron on the growth and yield of mustard *(Brassicacampestris* L.). They found that combined application of 40 kg S ha^{-1} along with 1 kg B ha^{-1} produced the maximum plant height, number of branches and leaves $plant^{-1}$, dry matter accumulation and yield attributes and yield of mustard.

Nayak *et al.* (2020) inferred that the highest seed yield of mustard was found with the treatment where sulphur was applied at the rate of 60 kg ha^{-1}.

Rana *et al.* (2020) reported that application of sulphur fertilization in mustard hybrid 'PAC 432' resulted increment in dry matter accumulation at different growth stages as well as harvest. Further, these treatments were also adjudged superior in terms of growth indices *viz.*, leaf area index (LAI), average growth rate (AGR), crop growth rate (CGR), leaf area duration (LAD) and biomass duration (BMD) in comparison to other treatments during the course of the trial. In relation to interactional effect of individual treatment variables, mustard hybrid 'PAC 432' fertilized with 60 kg S ha^{-1} produced maximum dry matter biomass while 'NRCHB-506' no sulphur application ensued least dry matter production.

Sharma *et al.* (2020) conducted a field experiment during 2017-18 to evaluate the effect of boron and sulphur on growth and yield attributes of mustard. They observed that highest plant height, number of branches $plant^{-1}$, dry matter accumulation, number of siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$, grain yield, stover yield and biological yield were maximum in the treatment of T_8- 100% RDF+ 2 kg B ha^{-1} + 45 kg S ha^{-1} and also significantly at par with T_9- 100% RDF + 3 kg B ha^{-1} +45 kg S ha^{-1}, T_6- 100% RDF + 2 kg B ha^{-1} + 30 kg S ha^{-1}, T_7- 100% RDF + 3 kg B ha^{-1} +30 kg S ha^{-1}.

A field experiment was conducted by Sultana *et al.* (2020) at Mymensingh to study the effect of sulphur and zinc nutrition to the seed yield and oil content of mustard during *rabi* season and observed that the number of branches $plant^{-1}$ (5.33), siliqua $plant^{-1}$ (261.8), seeds $siliqua^{-1}$ (17.58), 1000-seed weight (3.03 g), seed yield (1160 kg ha^{-1}), amount of oil content (39.35%) and stover yield (2535 kg ha^{-1}) was found maximum at the application of 60 kg S ha^{-1}.

Chaurasiya *et al*. (2019) conducted a field experiment at SVPUAT Meerut (U.P.) during rabi season of 2016 to study the effect of N and S nutrition on growth and yield of Indian mustard (*Brassica juncea* L.). They found that application of increased level of 120 kg N ha^{-1} and 40 kg S ha^{-1} significantly enhance growth and yield attributes of mustard.

Kumar *et al*. (2019) conducted a field experiment at agricultural farm of Visva Bharati, Sriniketan (W.B.), India during summer season 2016 and 2017 to study the effect of sulphur and boron nutrition on growth and productivity of summer sesame. They

concluded that the treatment combination of sulphur @ 45 kg ha^{-1} with 0.15% boron was found significant in recording higher values of growth and yield attributes and yield of sesame.

Singh *et al*. (2019) conducted a field experiment at research form NDUAT (Kumarganj), Ayodhya (U.P.) during rabi season 2015-16 to study the effect of different levels and sources of sulphur on yield of mustard (*Brassica juncea* L.). Results showed that grain yield (19.36 q ha^{-1}), stover yield (58.50 q ha^{-1}) and biological yield (77.86 q ha^{-1}) were significantly higher under RDF+ 40 kg S ha^{-1} through (Single Super Phosphate) SSP.

Islam *et al*. (2018) studied the effect of nitrogen (N) and sulphur (S) on yield and yield components of rapeseed. Study was carried out at Shere-Bangla agricultural university farm, Dhaka, Bangladesh during two consecutive rabi seasons of 2014-15 and 2015-16. Results revealed that the highest plant height, number of branches $plant^{-1}$, number of siliqua $plant^{-1}$, siliqua length, number of seeds $siliqua^{-1}$, 1000-seed weight, seed yield, stover yield, biological yield and harvest index were obtained from the combination of 120 kg N with 45 kg S ha^{-1}. They also found that application of 120 ka N ha^{-1} with 45 kg S ha^{-1} gave the maximum yield.

Kumar *et al.* (2018) evaluated the effect of levels and sources of sulphur on growth, yield, nutrient removal and relative economics of Indian mustard varieties under irrigated condition in 2015 at Varanasi. They observed that growth parameters, yield attributes, seed, stover yield and N, P, S removal by crop were enhanced by increasing sulphur levels.

At Uttar Pradesh, Meena *et al.* (2018) carried out a field experiment during 2016-2017 to assess the effect of biofertilizers and levels of sulphur on growth and yield of mustard [*Brassica juncea* (L.) Czern. & Coss]. They observed that growth parameters like plant height (167.50 cm), dry weight (44.40 g), number of branch $plant^{-1}$(6.80) and yield attributes such as number of siliqua $plant^{-1}$ (291.20) and test weight (4.51 g) were recorded at its maximum in the treatment T_{12} with the application of Azotobacter + Phosphate Solubilizing bacteria + 40 kg S ha^{-1} over the control.

Nath *et al.* (2018) conducted a field experiment in eastern Uttar Pradesh at the farm of Krishi Vigyan Kendra during 2014-15 and 2015-16 to assess the effect of sulphur fertilization on yield, sulphur uptake and oil content in Indian mustard under sandy

loam soil. They found that dual application of basal along with sulphur 80% WP 1.25 kg ha^{-1} foliar sprayed at 75 DAS had significant influence on yield attributes, grain yield, sulphur uptake and oil per cent in mustard. The highest average value of the parameters recorded are plant height (158.75 cm), seed $siliqua^{-1}$ (13.45), test weight (4.863 g), grain yield (21.86 q ha^{-1}) and oil content (33.73%).

Padma *et al*. (2018) they conducted a field experiment at college farm, CoA, Rajendranagar, Hyderabad during 2017 to evaluate the impact of sulphur on yield attributes and yield of maize. Results revealed that highest grain (5596 kg ha^{-1}) and stover yield (6995 kg ha^{-1}) was recorded by the treatment T_{10} (200-60-50-60 kg NPKS ha^{-1}). Nutrients were applied through Urea, DAP, MOP and bentonite sulphur respectively.

Rajput *et al*. (2018) studied the effect of sulphur levels (0, 20, 40 and 60 kg ha^{-1}) on mustard. The growth characters such as plant height, number of primary and secondary branches $plant^{-1}$, number of leaves $plant^{-1}$ and dry matter accumulation $plant^{-1}$ were maximum at 120 kg N ha^{-1} and 60 kg S ha^{-1}.

Sharma *et al*. (2018) carried out an experiment of studies on impact of sulphur with and without FYM on yield, uptake and methionine content in mustard in 2013-2015. They observed that the significant increase in seed yield of 1684.75 kg ha^{-1} and stover yield of 4739.82 kg ha^{-1} was recorded in the treatment of 60 kg S ha^{-1} and FYM 5 t ha^{-1} over the rest of the treatments.

Singh *et al*. (2018) assessed the effect of sulphur on yield of rajmash variety PDR 14. They found that application of sulphur proved to be beneficial in bringing about significant improvement in yield attributes. 30 kg S ha^{-1} produced highest grain yield 12.15 q ha^{-1}.

Solanki *et al.* (2018) conducted the field experiment with different levels of phosphorus, sulphur and two levels of seed inoculation and their effect on yield of mustard. They found that grain yield was significantly increased by the application of phosphorus, sulphur and PSB. They also reported that maximum grain yield was obtained with conjoint use of 50 kg P_2O_5 ha^{-1}, 50 kg S ha^{-1} along with PSB.

Suman *et al*. (2018) studied the effect of sulphur and phosphorus application on yield and N, P and K contents of soybean grown on vertisol. They found that the increasing

the application of sulphur and phosphorus, singly as well as in combination, significantly increased the grain yield and N, P and K contents over control.

Verma and Dawson (2018) reported that the maximum number of siliquae plant^{-1}, number of seeds siliqua^{-1}, test weight, seed yield, harvest index and oil content obtained in the sulphur at the rate of 30 kg. The maximum gross return obtained with the treatment of sulphur applied at 30 kg ha^{-1}. The maximum straw yield, net return and benefit cost ratio obtained with application of sulphur at 15 kg ha^{-1}.

Kumar *et al.* (2017) evaluated the effect of nitrogen and sulphur nutrition on growth and yield of Indian mustard in 2016. The results revealed that the growth and yield were increased with the application of 120 kg N ha^{-1} and 40 kg S ha^{-1}.

Negi *et al.* (2017) evaluated the effect of 2 sulphur sources on growth, yield and nutrient use efficiency of mustard in 2010 at N.E. Borlaug Crop Research Centre, Pantnagar. They found that the number of branches plant^{-1}, number of siliqua plant^{-1}, test weight and straw yield were highest with the application of 60 kg S ha^{-1} through zypmite.

Singh *et al*. (2017) studied the effect sulphur levels (0, 20 and 60 kg ha^{-1}) and four levels of boron (0, 1, 2 and 3 kg ha^{-1}) in mustard and it was revealed that the highest seed yield, protein and oil content of mustard were recorded with 60 kg S ha^{-1} which were statistically at par with 40 kg S ha^{-1} out significantly superior to other levels of sulphur. The seed yield of mustard at 40 kg S ha^{-1} was enhanced by 19.1% over control. The stover yield increased significantly up to 60 kg S ha^{-1} which was 51.1% higher than control.

Yadav *et al.* (2017) reported that Narendra Rai-8501 variety of mustard has utmost growth characters *viz.*, plant height, leaf area index, dry matter accumulation and number of branches plant^{-1} and yield attributes like number of siliqua plant^{-1}, number of seed siliqua^{-1}, length of siliqua (cm) and seed and stover yields over Varuna and Rohini with the application of 60 kg S ha^{-1}.

Varenyiova *et al.* (2017) carried out an experiment to assess sulphur nutrition and its effect on yield and oil content of oilseed rape (*Brassica napus* L.) within the agricultural cooperative in Mojmírovce during 2013-14. The result revealed that maximum yield of 3.96 t ha^{-1} was obtained with application of 40 kg ha^{-1} S and highest average oil production of 1809 kg ha^{-1} was found when 15 kg ha^{-1} S was applied.

Rakesh and Banik (2016) carried out a field experiment to assess the effect of sulphur levels and sources on growth, yield and quality of mustard in Terai region of West Bengal during 2013-2014. They reported that the growth parameters like plant height, number of branches plant^{-1} and yield parameters such as siliqua plant^{-1}, seeds siliqua^{-1}, 1000 seed weight, seed yield, and stover yield were increased at its maximum with the application of 25 kg S ha^{-1} as SSP.

Sisodiya *et al*. (2016) studied the effect of sulphur sources and levels on growth and quality of Groundnut (*Arachis hypogaea* L.). They found that maximum pod yield and total biomass production of groundnut increased with the application of elemental sulphur 20 mg kg^{-1}, whereas the application of Cosawet sulphur (S_1) @ 20 mg kg^{-1} showed significantly higher plant height.

Jaiswal *et al.* (2015) conducted a field experiment on effect of sulphur and boron on yield of mustard grown on Vindhyan red soil at Agricultural Research Farm of Rajiv Gandhi South Campus, Barkachha, Uttar Pradesh in 2013-2014. The study showed that maximum seed yield of 1.97-ton ha^{-1} was obtained with the application of RDF + 40 kg S ha^{-1} +2 kg B ha^{-1}.

Ray *et al.* (2015) performed a field experiment on effects of sulphur fertilization on yield, sulphur uptake and quality of Indian mustard under varied irrigation regimes in 2010- 2012. They observed that the maximum yield attributes and yield were obtained with 60 kg S ha^{-1}.

Debnath *et al.* (2014) reported from Kalyani (West Bengal) 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 in mustard.

Neha *et al.,* (2014) reported that application of 40 kg S ha^{-1} recorded significantly higher seed yield (19.6 q ha^{-1}) and straw yield (70.9 q ha^{-1}) over 20 kg S ha^{-1} and no sulphur. Further, increase in sulphur levels up to 60 kg S ha^{-1} remained at par with 20 and 40 kg sulphur ha^{-1}.

Ray *et al.* (2014) reported that yield of mustard was increased with the increasing dose of sulphur from 0 to 60 kg ha^{-1}. Higher yield was obtained with 60 kg S ha^{-1} that resulted in 17.9% increase over control.

Sah *et al.* (2013) reported that the application of sulphur at the rate of 45 kg/ha increased number of siliquae plant^{-1}, test weight (g), seed yield (q ha^{-1}) and straw yield (q ha^{-1}). Fertilization of 45 kg sulphur ha^{-1} produced the highest seed yield of 19.23 q ha^{-1} in comparison to 13.29 q ha^{-1} realized in control.

Tetarwal *et al.* (2013) conducted a field experiment at Aklera, Jhalawar to find out the suitable sulphur source. Bentonite sulphur gave significantly higher growth, yield attributes, seed and oil yield then other sources of sulphur.

Piri *et al.* (2012) carried out an experiment on effect of sulphur fertilizer on sulphur uptake and forage yield of mustard in condition of different regimes of irrigation at Indian Agricultural Research Institute, New Delhi during 2007-2009. The study showed that number of primary branches of plant was more with the application of 45 kg S ha^{-1} and also noticed significant increase of sulphur content in forage and sulphur uptake with increasing level of sulphur.

Upadhyay (2012) reported that significant response of crop was obtained up to 40 kg S ha^{-1} in seed and stover yield. The result shows that seed yield of 20.57 q ha^{-1} and stover yield of 58.48 q ha^{-1} was attained with the application of 40 kg S ha^{-1} which is 36.8 and 39.8% more as compared to the control.

Verma *et al*. (2012) observed that application of fertilizers 120 kg N + 45 kg S ha^{-1} in mustard gave significantly higher plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1}, dry matter accumulation plant^{-1}, siliquae length, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, 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.

Mohiuddin *et al.* (2011) reported that the plant height; branches plant^{-1}, siliquae plant^{-1}, seed, stover yield and biological yield increased with increasing S levels significantly up to 16 kg S ha^{-1}.

Kapur *et al.* (2010) reported that plant height of mustard was recorded significantly higher with application of 60 kg S ha^{-1} but it was at par with 45 kg S ha^{-1} and 30 kg S ha^{-1} levels.

Shelly and Virender (2010) reported that split application of Sulphur resulted in a significantly higher number of primary branches and siliquae plant^{-1} and seeds siliqua^{-}

[1]. The higher seed yield was obtained with application of sulphur as one fourth at sowing one half at vegetative stage + one fourth at 50% flowering.

Thuan and Rana (2010) reported from IARI, New Delhi that application of sulphur @ 40 kg ha^{-1} produced 19.3% higher seed yield than control plot.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to study the systems of mustard intensification as influenced by variety and sulphur. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from October 2020 to February 2021 in *Rabi* season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted both in the Central Laboratory & Agronomy Field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.2.5 System of mustard intensification

The system, known as System of Mustard Intensification (SMI) allows resource poor farmers to use less water and seeds and yet achieve significantly higher yields. This technology essentially advocates a radically different package of practices and has earlier been successfully tried in crops like rice and wheat. The principal of the SMI method is based on low seed rate, seed priming, transplanting young seedlings, wide a uniform spacing of single plants and application of enough organic manure.

3.3 Experimental materials

Mustard variety namely BARI Sarisha-9, BARI Sarisha-14 and BARI Sarisha-15 were used as experimental materials for this experiment. The important characteristics of the variety is mentioned below:

BARI Sarisha-9

BARI Sarisha-9 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The variety was released, in the year of 2000.Short durated variety, plant height 80-95 cm, 4-6 primary branch are present in each plant, leaf light green and smooth, blooming flower in upright position on axils, stem coated by pedicel of leaf, flower is yellow, number of siliqua /plant 80-100, seed color pink, seed/siliqua 15-20, 1000 seed weight 2.5-3.0 g. It is easily cultivated because of short life.It's planting in Rabi season from mid October to mid Novembergiven yield 1.25-1.45 t/ha having Oil content 43-44%.

BARI Sarisha-14

BARI Sarisha-14 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Developed by crossing between Tori and Sonali Sarisha and released, in the year of 2006. Short duration variety, plant height 75-85 cm, leaf

light green, smooth, siliqua/plant 80-102, two chambers are present in pod but as like as four chambers. Seed/siliqua 22-26, seed color pink, 1000 seed weight 3.5-3.8 g, crop duration 75-80 days, after harvest aman and before transplant boro. It is easily cultivated because of short duration. It's planting in Rabi season from mid October to mid November given yield 1.45-1.60 t/ha having Oil content 44-45%.

BARI Sarisha-15

BARI sarisha14 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. It was developed by selection from local germplasm and released, in the year of 2006. Short durated variety, plant height 90-100 cm, siliqua/plant 70-80, two chambers are present in pod, seed/siliqua 20-22, pod is narrow and taller than BARI sarisha-14, seed color yellow, 1000 seed weight 3.25-3.50 g, crop duration 80-85 days, after harvest aman and before transplant boro, it is easily cultivated because of short duration. It's planting in rabi season from mid October to mid November. Yield performance is 1.45-1.60 t/ha and Oil content is 48-52%.

3.4 Seed collection

Seeds of BARI Sarisha-9, BARI Sarisha-14 and BARI Sarisha-15 were collected from Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

3.5 Experimental treatment

There were two factors in the experiment namely mustard variety and different fertilizer doses as mentioned below:

Factor A: Mustard varieties (3) *viz;*

V_1 = BARI Sarisha-9,
V_2 = BARI Sarisha-14 and
V_3 = BARI Sarisha-15

Factor B: Different doses of sulphur (4) *viz;*

S_0 = Control,
S_1= 25 % less than recommended dose of sulphur fertilizer (RDS),
S_2= RDS and
S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

3.6 Details of experimentation

3.6.1 Raising and transplanting of mustard seedlings

Seeds were sown in small area of well-prepared seedbed inside of the main field. Seedbed was well ploughed and enough fertilizers for germination of seedlings. Seed sowing in the seed bed was 8 October, 2020.Seedling transplanting in the main was 27 October, 2020 The seedlings were grown under natural light, temperature, and moisture. The seedlings were thinned to one after the true leaf appeared in each well. The soil was monitored by a soil moisture detector to avoid drought stress. Soil with moisture less than 70% was considered to have light drought stress and was supplied with water. Weeds and pests were controlled by using normal practices.

3.6.2 Land preparation

The experimental land was opened with a power tiller on 15 October, 2020. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on date 25 October, 2020 and was ready for transplanting seedling.

3.6.3 Experimental design

The experiment was laid out in randomized complete block design with 2 factor and three replications. There are 12 treatment Interaction and 36 unit plots. The unit plot size was 3.75 m^2 (2.5 m × 1.5 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. The layout of the experimental field was shown in Appendix- IV.

3.6.4 Fertilizer application

The following fertilizers with their corresponding rates were applied as followed:

Fertilizers	Quantity/requirement (kg ha^{-1})
Urea	250
TSP	170
MoP	85
Gypsum	150
Boric Acid	10
Cow dung	8000

Source: (BARI Krishi Projukti hatboi-2019 recommendation)

Urea, triple superphosphate (TSP),Muriate of potash (Mop), gypsum, boric acid and cow dung were used as sources of nitrogen, phosphorus, potassium, sulphur, zinc, boron and others nutrient respectively. Total amount of TSP, MP, boric acid, cow-dung and one and half amount of urea were applied at final land preparation. Gypsum as the source of sulphur was also applied during final land preparation as par treatment requirement. The rest amount of urea was applied during flower initiation of mustard (BARI, 2019).

3.7 Intercultural operations

i) Weeding

Weeding was done at 15 and 40 days after transplanting.

ii) Irrigation

Optimum irrigation was given to every plot for ensure soil moisture by using water can. Continuously four days irrigation was given for establishing the young seedlings. First irrigation was given at 15 days after transplanting and the second irrigation at 40-45 days after transplanting. A little irrigation was given at 55-60 days after transplanting.

iii) Application of pesticides

In the experimental field mustard crops were attacked by aphids (*Lipaphis erysimi*. K). Malathion 57 EC at the rate of 2 ml/litre of water was applied for controlling aphids attack in the field. Spraying of pesticide was done in the afternoon while the pollinating bees were away from the experimental field.

3.8 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant.

3.9 Harvesting and processing

From the experimental field, mustard crop was harvested at maturity when 80% of the siliquae turned into straw yellowish in color. Harvesting was done in the morning to avoid shattering. Crops were harvested from the pre demarcated area of 1 m^2 at the centre of each plot at ground level with the help of a sickle for grain and stover yield.

Prior to harvesting, five plants were sampled randomly from each plot, were bundled separately, tagged them and brought to a clean cemented threshing floor from which different yield parameters were recorded. The crop was dried in the sun properly by spreading them over floor and seeds were separated from the siliquae by beating the bundles with the help of bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The stovers were also dried in the sun. Seed and stover yield were recorded. The biological yield was calculated as the sum of the seed yield and stover yield.

3.10 Data collection

The data were recorded on the following parameters;

a) Growth parameters

i. Plant height (cm)
ii. Number of branches plant^{-1}
iii. Above ground dry matter weight plant^{-1} (g)

b) Yield contributing characters

i. Siliqua plant^{-1} (no.)
ii. Length of siliqua (cm)
iii. Seeds siliqua^{-1} (no.)
iv. 1000-seed weight (g)

c) Yield characters

i. Seed yield (t ha^{-1})
ii. Stover yield (t ha^{-1})
iii. Biological yield (t ha^{-1}) and
iv. Harvest index (%)

3.11 Procedure of recording data

i) Plant height (cm)

The height of the 5 randomly selected plants was measured from the ground level to the tip of the plants at 30, 45, 60 days after transplanting and at harvest. Mean plant height of mustard was calculated and expressed in cm.

iii) Number of branches plant^{-1}

The branches plant^{-1}were counted from five randomly sampled plants. It was done by counting total number of secondary branches of all sampled plants then the average data were recorded. Data on different parameters were recorded at 30, 50 days after transplanting and harvest.

iii) Above ground dry matter weight plant^{-1}(g)

Five plants were collected randomly from each plot at 30, 50 days after transplanting and harvest respectively. The sample plants were oven dried for 72 hours at 70°C and then dry matter content was determined. Mean dry matter plant^{-1} of mustard plant were calculated and expressed in gram (g) plant^{-1}.

iv) Number of siliqua plant^{-1}

Siliqua plant^{-1} was counted from the 5 randomly selected plant samples and then the average siliqua was calculated.

v) Length of siliqua (cm)

Length of 5 siliquae that collected randomly from the sampled plants were recorded and the mean length was calculated.

vi) Seeds siliqua^{-1} (no.)

Seeds siliqua^{-1} was counted from splitting five siliquae which were collected randomly from sample plants and then mean value was calculated.

vii) 1000-seed weight (g)

1000 seeds were counted randomly from the seeds of each sample plant, then weighed it in an electrical balance in gram (g).

viii) Seed yield (t ha^{-1})

The mean seed weight was taken by threshing the plants of each sample area and then converted to t ha^{-1} in dry weight basis.

ix) Stover yield (t ha^{-1})

The stover yield of mustard was calculated after threshing and separation of the seeds from the plant of sample area and then expressed in t ha^{-1} on dry weight basis.

x) Biological yield (t ha^{-1})

The summation of seed yield and above ground stover yield is regarded as the biological yield. It was calculated as,

Biological yield =Grain yield + Stover yield.

xii) Harvest index (%)

Harvest index was calculated on dry weight basis with the help of following formula.

Harvest index (HI) = $\frac{\text{Grain yield}}{\text{Biological yield}} \times 100\ \%$

Here, Biological yield = Grain yield + stover yield

3.12 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program named Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

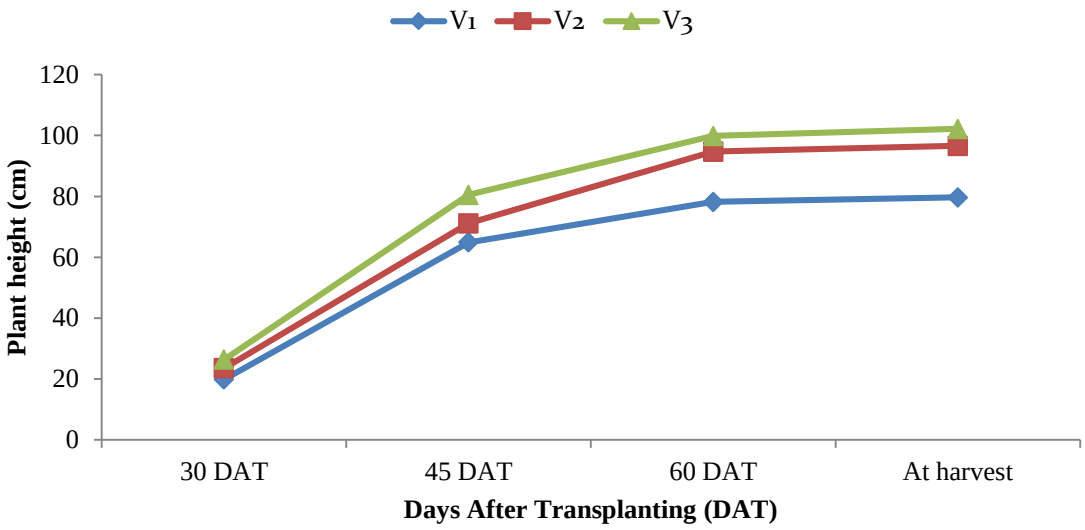
Results obtained from the present study have been presented and discussed in this chapter with a view to study the systems of mustard intensification influenced by variety and sulphur. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of variety

Plant height is an essential character of the vegetative stage of the crop plant and indirectly affects the yield of crop plants. Different variety significantly influenced plant height of mustard at different days after transplanting (DAT). It was seen that height increased with the age of the crop up to harvest. The plant height reached the highest value at maturity (Figure 1). Experimental result revealed that the highest plant height (26.39, 80.52, 99.88 and 102.20 cm) at 30, 45, 60 DAT and at harvest, respectively was observed in V_3 (BARI Sarisha-15) treatment. Whereas the lowest plant height (19.85, 64.91, 78.18 and 79.65 cm) at 30, 45, 60 DAT and at harvest respectively was observed in V_1 (BARI Sarisha-9) treatment. The variation of plant height is probably due to the genetic make-up of the variety..Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical makeup. Tyeb *et al.* (2013) also reported that the variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic makeup of the cultivars.



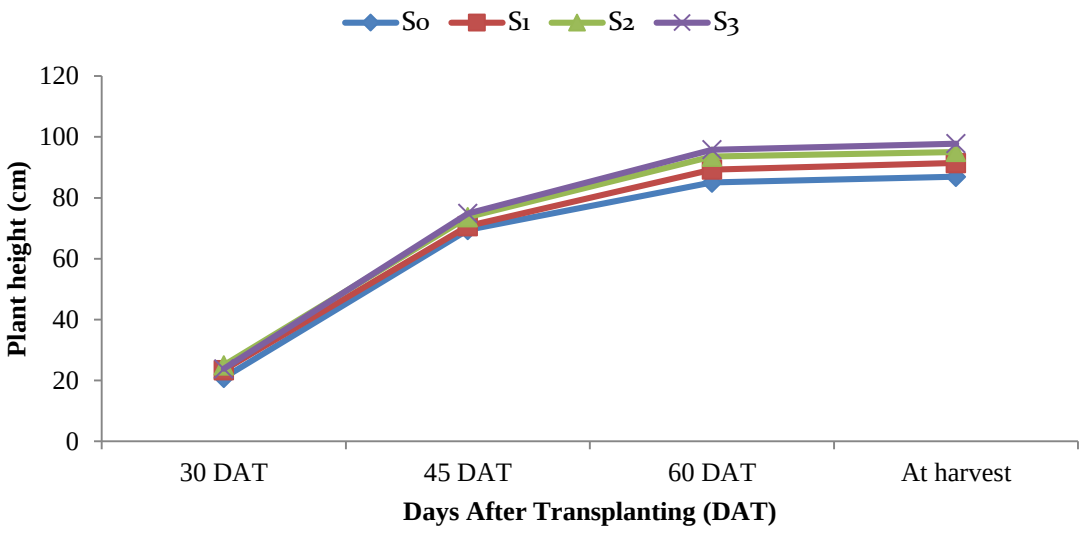
Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 1. Effect of variety on plant height of mustard at different days after transplanting (LSD $_{(0.05)}$ =1.13, 1.71, 2.78 and 2.85 at 30, 45, 60 days after transplanting and at harvest respectively).

Effect of sulphur

Significant variance in mustard plant height was observed as a result of various doses of sulphur application at different days after transplanting (Figure 2). Experimental result showed that the highest plant height (24.99 cm) at 30 DATwas observed in S_2 (Recommended dose of sulphur fertilizer treated plot) treatment which was statistically similar with (23.83 cm) S_3 (25 % more than recommended dose of sulphur fertilizer) treatment. At 45, 60 DAT and at harvest the highest plant height (74.86. 95.80 and 97.82 cm) was observed in S_3 treatment which was statistically similar with (73.69, 93.55 and 95.07 cm) S_2 treatment at 45, 60 DAT and at harvest, respectively. While the S_0 (Control) treatment had the lowest plant height (20.86, 69.48, 85.06 and 86.91 cm)at 30, 45, 60 DAT and at harvest respectively which was statistically similar with (70.72 cm) S_1 treatment at 45 DAT.The increase in plant height due to adequate availability of sulphur attributed to better nutritional environment for plant growth at active vegetative stages as a result of enhancement in multiplication, cell elongation and cell expansion in the plant body which ultimately increased the height of plant. The results of present investigation are in agreement with the finding ofAwal *et al.* (2020) who reported that

combined application of 40 kg S ha^{-1} along with 1 kg B ha^{-1} produced the maximum plant height.



Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 2. Effect of sulphur on plant height of mustard at different days after transplanting (LSD $_{(0.05)}$ =1.30, 1.97, 3.21and 3.29 at 30, 45, 60 days after transplanting and at harvest respectively).

Combined effect of variety and sulphur

Variety and sulphur application had shown significant effect on mustard plant height at different days after transplanting. (Table 1). The results of the experiment showed that the V_3S_3treatment combination, which was statistically similar withV_3S_3 (27.67cm) and with V_2S_2 (25.93 cm) treatment combination had the highest plant height (28.13 cm) at 30 DAT. However, at 45 DAT the highest plant height (83.20 cm) was observed in V_3S_2treatment combination which was statistically similar withV_3S_3 (80.93 cm) treatment combination. At 60 DAT and at harvest the highest plant height (106.13 and 109.00 cm) was observed in V_3S_3treatment combination which was statistically similar withV_3S_2 (104.80 and 104.67 cm) treatment combination at 60 DAT and at harvest, respectively. V_1S_0 treatment combination showed the lowest plant height (15.20, 60.50,72.53 and 71.87 cm) at 30, 45, 60 DAT and at harvest, respectively which was statistically comparable to V_1S_1 treatment combination at different DAT.

Table 1. Combined effect of variety and different sulphur levels on plant height of mustard at different days after transplanting

Treatment combinations	Plant height (cm)			
	30 DAT	45 DAT	60 DAT	At harvest
V_1S_0	15.20 e	60.50 e	72.53 f	71.87 f
V_1S_1	20.87 d	62.41 e	74.80 f	76.27 f
V_1S_2	21.37 d	67.60 d	82.93 e	85.94 e
V_1S_3	21.97 d	69.13 d	82.47 e	84.53 e
V_2S_0	22.67 cd	69.53 d	90.27 d	93.60 d
V_2S_1	24.30 bc	70.23 d	96.93 bc	98.27 cd
V_2S_2	25.93 ab	70.27 d	92.93 cd	94.60 cd
V_2S_3	21.40 d	74.53 c	98.80 b	99.93 bc
V_3S_0	24.71 bc	78.40 b	92.37 cd	95.27 cd
V_3S_1	25.07 b	79.53 b	96.20 bc	99.87 bc
V_3S_2	27.67 a	83.20 a	104.80 a	104.67 ab
V_3S_3	28.13 a	80.93 ab	106.13 a	109.00 a
$LSD_{(0.05)}$	2.26	3.42	5.56	5.71
CV(%)	5.75	2.80	3.61	3.64

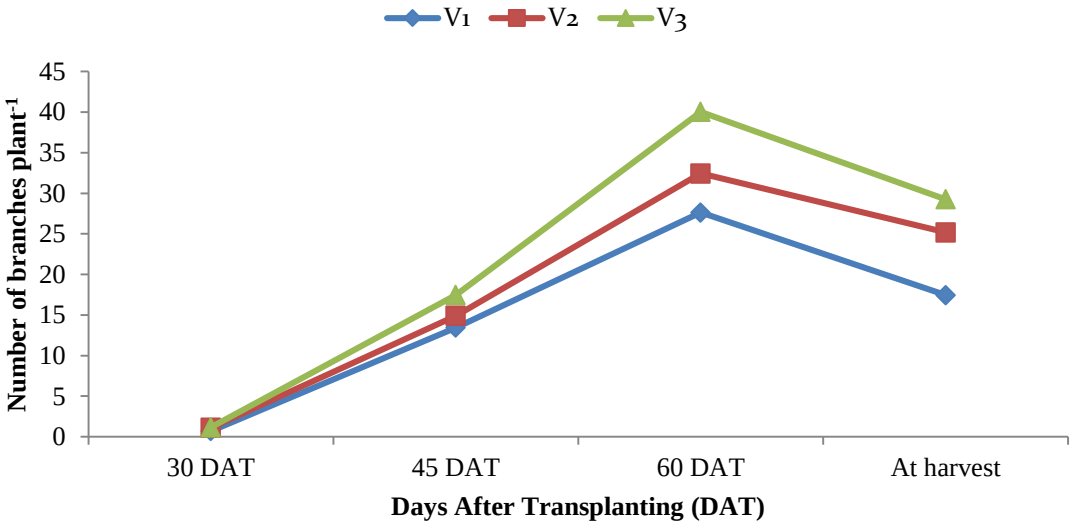
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

4.1.2 Number of branches plant^{-1}

Effect of variety

Depending on the variety, mustard branches plant^{-1}varied significantly at different days after transplanting (DAT). According to the experimental results, the V_3 (BARI Sarisha-15) treatment had the highest number of branches plant^{-1} (1.15, 17.47, 40.04 and 29.27) at 30, 45, 60 DAT and at harvest, respectively. V_1(BARI Sarisha-9) treatment, had the lowest number of branches plant^{-1}(0.70, 13.45, 27.62 and 17.45) at 30, 45, 60 DAT and at harvest, respectively (Figure 3). The reason of difference in number of branches plant^{-1}was the genetic makeup of the variety, which was primarily

influenced by heredity.Helal *et al.* (2016)also found similar result which supported the present finding and reported that higher number of branches plant^{-1} is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.



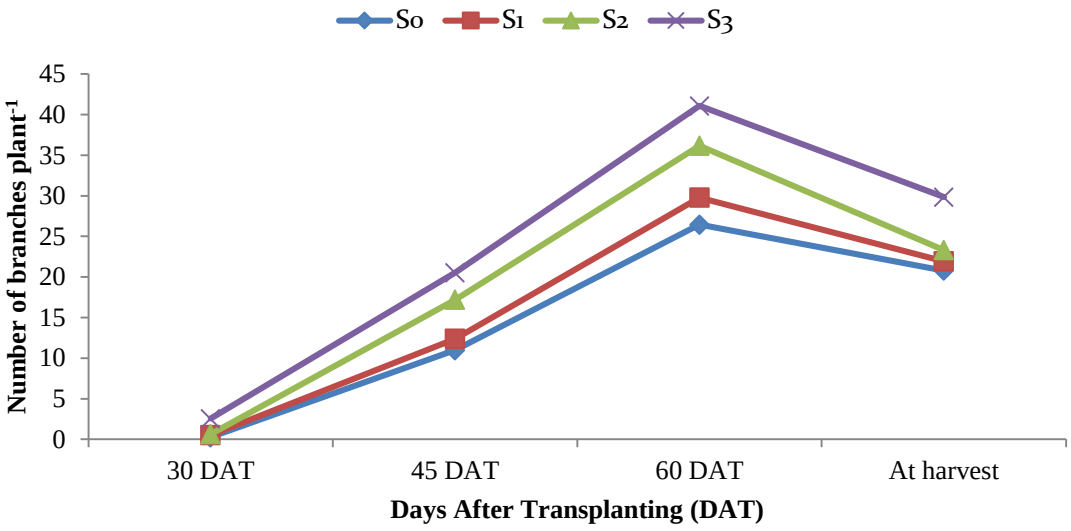
Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 3. Effect of variety on number of branches plant^{-1}of mustard at different days after transplanting (LSD $_{(0.05)}$ =0.04, 0.98, 1.94 and 1.04 at 30, 45, 60 days after transplanting and at harvest respectively).

Effect of sulphur

Different doses of sulphur application at various days after transplanting had shown significant effect in respect of number of branches plant^{-1} of mustard (Figure 4). According to the experimental results, the S_3 (25 % more than recommended dose of sulphur fertilizer) treatment had the highest number of branches plant^{-1}(2.55, 20.53, 41.08 and 29.85) at 30, 45, 60 DAT and at harvest respectively. While the lowest number of branches plant^{-1}(0.25, 10.99, 26.44 and 20.78) at 30, 45, 60 DAT and at harvest respectively was found inS_0 treatment (Figure 4). Increase in number of branches plant^{-1} might be due to availability of nutrient in adequate amount resulted in increased of photosynthesis, which promote metabolic activity, increase the cell division, ultimately increase the number of primary branches plant^{-1}. Improved nutritional condition with sulphur fertilization would have attributed to this response as sulphur in consequent of chlorophyll, protein and many biologically active compounds

which might have accelerated photosynthetic rate and growth.Awal *et al.* (2020) reported that application of 40 kg S ha^{-1} significantly influenced growth attributes of mustard. Negi *et al.* (2017) also found similar result which supported the present finding and reported that the number of branches $plant^{-1}$ was highest with the application of 60 kg S ha^{-1} through gypsum.



Here, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 4. Effect of sulphur on number of branches $plant^{-1}$of mustard at different days after transplanting (LSD $_{(0.05)}$ = 0.05, 1.14, 2.24 and 1.20at 30, 45, 60 days after transplanting and at harvest respectively).

Combined effect of variety and sulphur

At various days after transplanting, the treatment combination of variety and sulphur had shown significant effect on the number of branches $plant^{-1}$ of mustard (Table 2). The experimental findings revealed that the V_3S_3 treatment combination, which was statistically similar with V_3S_2(48.70) treatment combination at 60 DAT had the highest number of branches $plant^{-1}$ (3.47, 24.13, 52.57 and 33.60) at 30, 45, 60 DAT and at harvest respectively. While the lowest number of branches $plant^{-1}$ of mustard (0.20, 10.03, 21.93 and 13.80) at 30, 45, 60 DAT and at harvest respectively was found in V_1S_0 treatment combination which was statistically similar with V_1S_1 (0.27) treatment combination at 30 DAT; with V_1S_1 (10.03) and V_2S_0 (11.73) treatment combination at

60 DAT and with V_1S_1 (13.93), V_1S_2 (15.80) and V_2S_0 (15.73) treatment combination at harvest respectively.

Table 2. Combined effect of variety and different sulphur levels on number of branches plant^{-1} of mustard at different days after transplanting.

Treatment combinations	No. of branches plant^{-1}			
	30 DAT	45 DAT	60 DAT	At harvest
V_1S_0	0.20 h	10.03 g	21.93 f	13.80 f
V_1S_1	0.27 h	10.03 g	26.27 e	13.93 f
V_1S_2	0.53 f	14.20 de	27.00 e	15.80 f
V_1S_3	1.80 c	19.53 c	35.27 b	26.27 c-e
V_2S_0	0.47 fg	11.73 fg	28.27 e	15.73 f
V_2S_1	0.87 d	14.50 de	33.33 bc	27.20 cd
V_2S_2	0.69 e	15.47 d	32.80 b-d	28.13 bc
V_2S_3	2.40 b	17.93 c	35.33 b	29.67 b
V_3S_0	0.07 i	11.20 fg	29.13 de	32.80 a
V_3S_1	0.42 g	12.60 ef	29.77 c-e	24.67 e
V_3S_2	0.67 e	21.93 b	48.70 a	26.00 de
V_3S_3	3.47 a	24.13 a	52.57 a	33.60 a
$LSD_{(0.05)}$	0.09	1.97	3.89	2.08
CV(%)	5.89	7.62	6.90	5.14

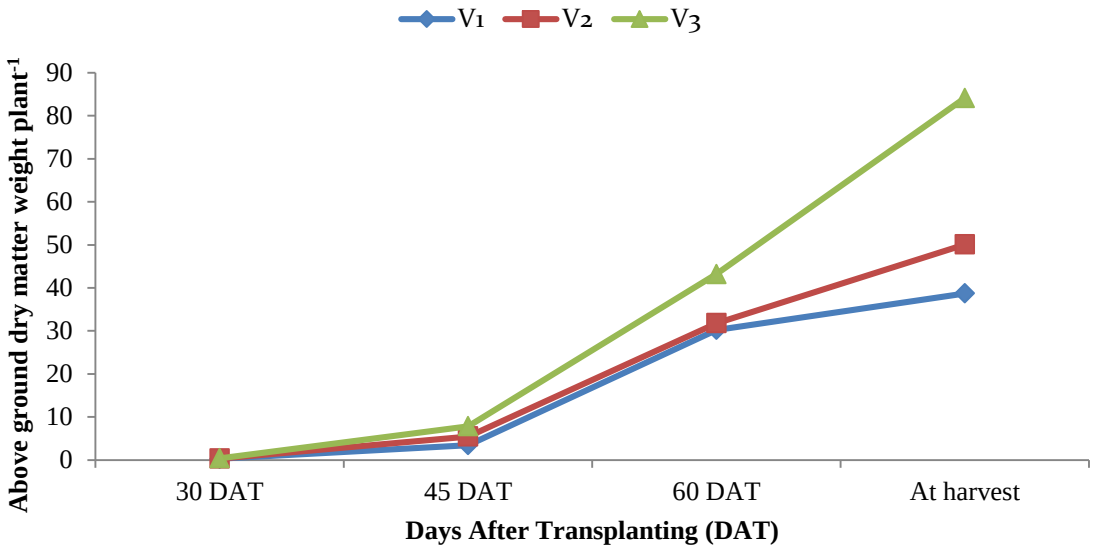
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

4.1.3 Above ground dry matter weight plant^{-1}

Effect of variety

The result of the experiment showed that different varieties had significant effect on the above ground dry matter plant^{-1} of mustard at various days after transplanting (Figure 5). According to the experimental result it was revealed that, the highest above ground dry matter plant^{-1} (0.40, 7.84, 43.21 and 84.12 g) at 30, 45, 60 DAT and at harvest respectively was found in V_3 (BARI Sarisha-15) treatment. Whereas the lowest above

ground dry matter plant^{-1} of mustard (0.28, 3.43, 30.22 and 38.72 g) 30, 45, 60 DAT and at harvest respectively was found in V_1 (BARI Sarisha-9) treatment. The reason why the dry weight plant^{-1} varies between different varieties is because each variety has a unique growth stage and makes use of resources from its environment differently. Patel *et al.* (2015) reported that mustard varieties significantly differed in dry weight plant^{-1}and this difference may bedue to varietal behavior. Rashid *et al.* (2010) also reported that the different varieties, which produced a different type of siliqua, and thus, the DM (Dry matter) varied significantly.



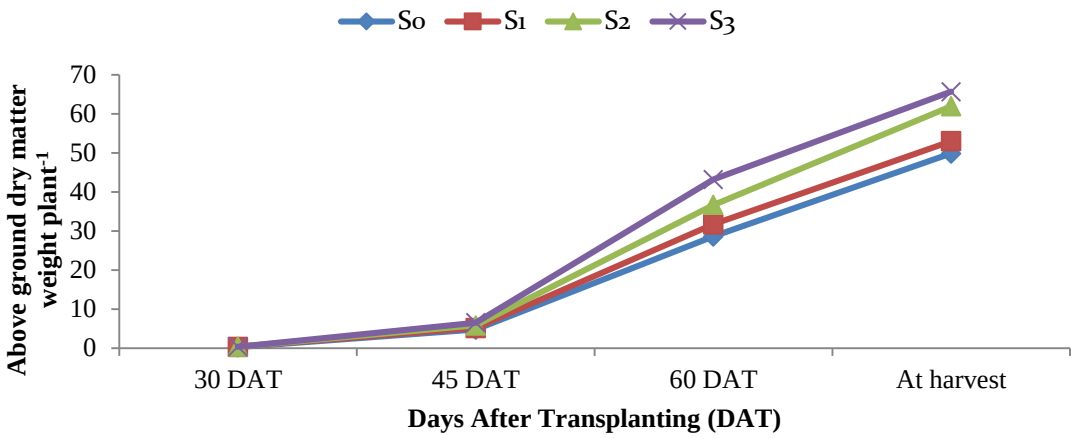
Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 5. Effect of variety on number of above ground dry matter weight plant^{-1} of mustard at different days after transplanting (LSD $_{(0.05)}$ = 00.01, 0.24, 1.50 and 2.48 at 30, 45, 60 days after transplanting and at harvest respectively).

Effect of sulphur

Application of sulphur fertilizer had shown significant effect on above ground dry matter weight plant^{-1} of mustard at various days after transplanting (Figure 6). According to the findings experimental results showed that, the S_3 treatment had the highest above ground dry matter plant^{-1}(0.38, 6.54, 43.22 and 65.72 g) at 30, 45, 60 DAT and at harvest respectively which was statistically comparable with the S_2(0.36 g) treatment at 30 DAT. However, the S_0 (Control) treatment, was found to had the lowest above ground dry matter plant^{-1} (0.26, 4.74, 28.64 and 49.87 g) at 30, 45, 60 DAT and

at harvest, respectively. Dry matter production successively increased till maturity due to favourable effect of sulphur on the growth and development of plants. Increase in number of branches plant^{-1}, and plant height is directly responsible for increasing the dry matter accumulation in plants at higher levels of sulphur.Rana *et al.* (2020) reported that application of sulphur fertilization in mustard hybrid 'PAC 432' resulted increment in dry matter accumulation at different growth stages as well as harvest. Similar result was also observed by Rajput *et al.* (2018) who reported that the growth characters such as dry matter accumulation plant^{-1} was maximum at 120 kg N ha^{-1} and increased sulphur application *i.e.* @ 60 kg S ha^{-1}.



Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 6. Effect of sulphur on number of above ground dry matter weight plant^{-1} of mustard at different days after transplanting (LSD $_{(0.05)}$ = 0.02, 0.28, 2.18 and 2.87at 30, 45, 60 days after transplanting and at harvest respectively).

Combined effect of variety and sulphur

The above ground dry matter plant^{-1} of mustard at various days after transplanting was significantly influenced as a result of the variety and sulphur combination treatment. (Table 4). The experimental findings revealed that the V_3S_3 treatment combination had the highest above ground dry matter plant^{-1} of mustard (0.43, 9.42, 49.25 and 99.43 g)at 30, 45, 60 DAT and at harvest respectively which was statistically similar with V_1S_2treatment combination(0.43, 8.66 and 47.10 g) at 30, 45 and 60 DAT. V_1S_0 treatment combination had the lowest above ground dry matter plant^{-1} of mustard (0.22,

3.30, 21.00 and 34.08 g) at 30, 45, 60 DAT and at harvest, respectively which was statistically similar with V_1S_1 (3.45 g), V_1S_2 (3.44 g) andV_1S_3 (3.45 g) treatment combination at 45 DAT and with V_1S_1 (35.80 g)treatment combination at harvest, respectively.

Table 3. Combined effect of variety and different sulphur levels on above ground dry matter weight plant^{-1} of mustard at different days after transplanting.

Treatment combinations	Above ground dry matter weight plant^{-1} (g)			
	30 DAT	45 DAT	60 DAT	At harvest
V_1S_0	0.22 g	3.30 f	21.00 g	34.08 g
V_1S_1	0.28 f	3.45 f	30.17 e	35.80 g
V_1S_2	0.29 f	3.44 f	31.65 e	42.46 f
V_1S_3	0.31 ef	3.52 f	38.06 cd	42.54 f
V_2S_0	0.24 g	4.37 e	28.62 ef	44.79 f
V_2S_1	0.23 g	5.34 d	24.88 f	46.82 f
V_2S_2	0.36 cd	5.44 d	31.31 e	53.56 e
V_2S_3	0.39 bc	6.69 c	42.36 b	55.20 e
V_3S_0	0.33 de	6.55 c	36.30 d	70.74 d
V_3S_1	0.42 ab	6.74 c	40.20 bc	76.44 c
V_3S_2	0.43 a	8.66 b	47.10 a	89.88 b
V_3S_3	0.43 a	9.42 a	49.25 a	99.43 a
$LSD_{(0.05)}$	0.03	0.49	3.78	4.97
CV(%)	6.26	5.19	6.37	5.10

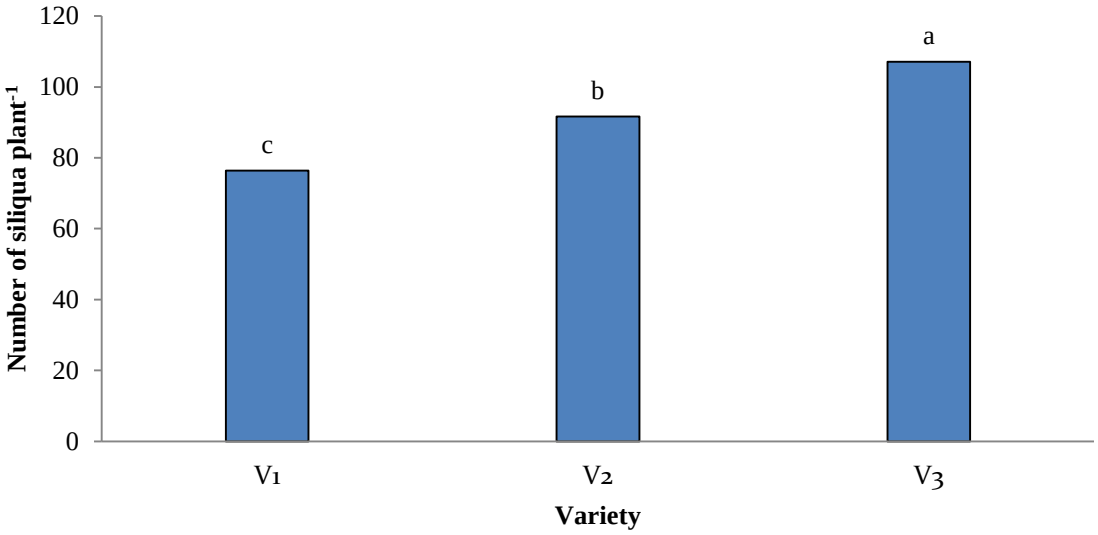
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

4.2 Yield contributing characters

4.2.1 Number of siliqua plant^{-1}

Effect of variety

The number of siliqua plant^{-1} of mustard was significantly influenced by different varieties (Figure 7). Experimental result revealed that the highest number of siliqua plant^{-1} of mustard (107.11) was found in V_3 (BARI Sarisha-15) treatment. The lowest number of siliqua plant^{-1} of mustard (76.35) was found in V_1 (BARI Sarisha-9) treatment. Different mustard varieties had different number of siliqua plant^{-1} due to the genetic makeup of the variety and maximum number of siliqua plant^{-1} was obtained from high yielding varieties comparable to low yielding mustard varieties. The result obtained from the present study was similar with the findings of Sarker *et al*. (2021), who reported that the largest number of siliquae/plant was recorded in BARI Sarisha-16, which was considerably different from other varieties. Mustard varieties have a considerable impact on yield and yield parameters.

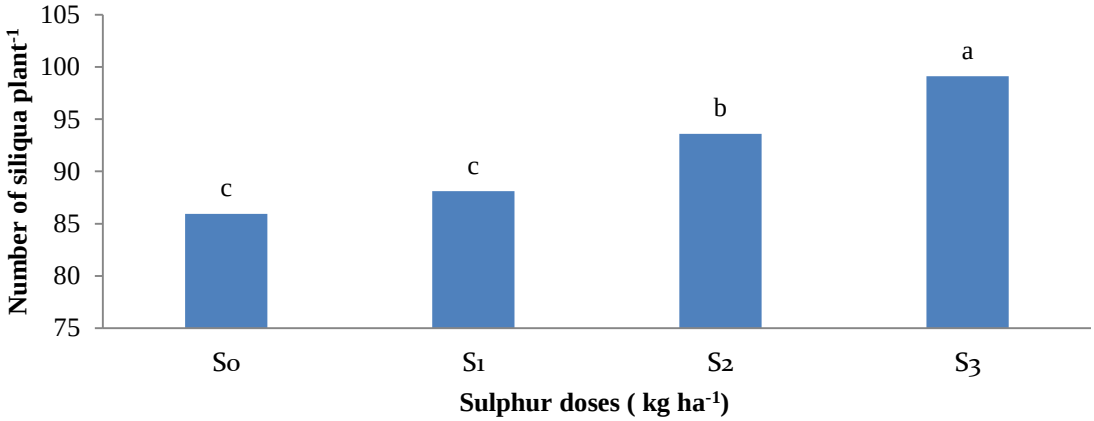


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 7. Effect of variety on number of siliqua plant^{-1} of mustard (LSD $_{(0.05)}$ = 3.61).

Effect of sulphur

The different doses of sulphur application had a significant effect on the number of siliqua plant^{-1} of mustard (Figure 8). According to the experimental results, the highest number of siliqua plant^{-1} of mustard (99.11) was observed in the S_3 (25 % more than recommended dose of sulphur fertilizer) treatment. However, the S_0 (Control) treatment had the lowest number of siliqua plant^{-1} of mustard (85.93) which was similar with S_1 (88.11) treatment. The balanced nutritional environment enhanced the nutrient assimilation which in turn accelerated the crop to put forth the maximum yield attributes and yield. Sulphur helps in the synthesis of protein, which in turn produce photosynthates and adequate partition and translocation of this metabolites to the reproductive organ might have lead to the production of high yield contributing characters and yield. Sultana *et al*. (2020) reported that the number of siliqua plants^{-1} ((17.58) increased to its highest level when increased amount (@60 kg S ha^{-1}) of sulphur fertilizer was applied.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 8. Effect of sulphur on number of siliqua plant^{-1} of mustard (LSD $_{(0.05)}$ = 4.17).

Combined effect of variety and sulphur

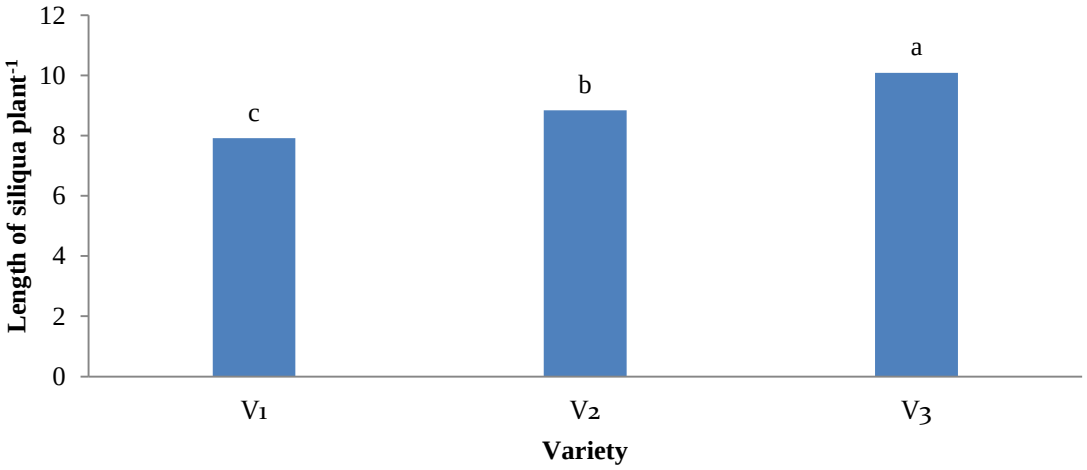
Mustard siliqua plant^{-1} was significantly influenced by variety and different levels of sulphur application. (Table 4). Experimental result revealed that the highest number of

siliqua plant^{-1} of mustard (116.33) was observed in V_3S_3 treatment combination which was statistically similar with V_3S_2(111.03) treatment combination. While the lowest number of siliqua plant^{-1} of mustard (70.07) was observed in V_1S_0 treatment combination which was statistically similar with V_1S_1 (75.33) treatment combination.

4.2.2Length of siliqua plant^{-1}

Effect of variety

The length of siliqua of mustardwas significantly influenced by various mustard varieties (Figure 9). The highest length of siliqua of mustard (10.08 cm) was observed in the V_3 (BARI Sarisha-15) treatment. While the V_1 treatment (BARI Sarisha-9) had the lowest length of siliqua of mustard (7.92 cm). Length of siliqua plant^{-1} varies between mustard varieties because of the variety's genetic makeup. The result obtained from the present study was similar with the findings ofTripathi *et al.* (2021) who reported that the variation of siliqua length of the different mustard cultivars differed significantly due to the genetic makeup of the varieties.

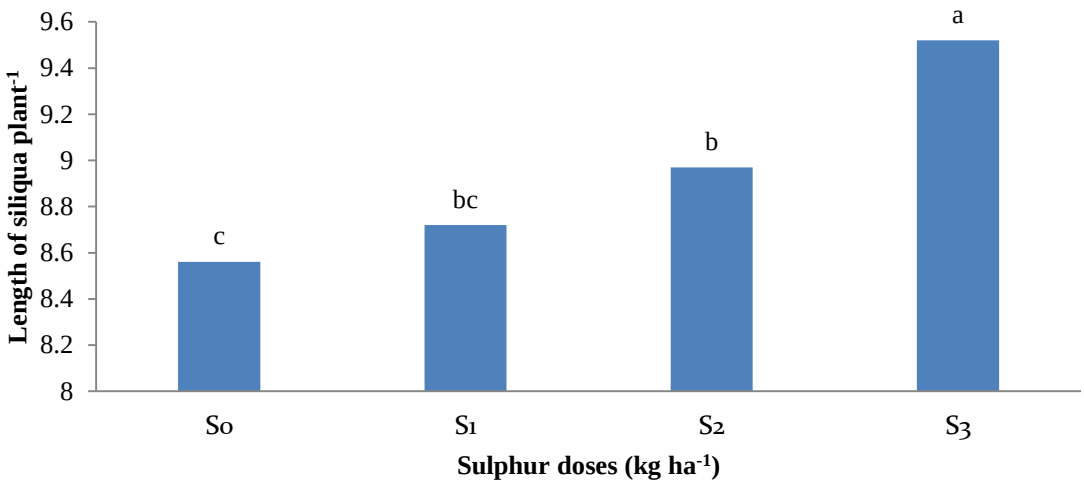


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 9. Effect of variety on length of siliquaof mustard (LSD $_{(0.05)}$ = 0.27).

Effect of sulphur

Different levels of sulphur applied in the experimental field showed significant effect on the siliqua length of mustard (Figure 10). Experimental result showed that thehighest length of siliqua of mustard (9.52 cm) was observed in the S_3(25 % more than recommended dose of sulphur fertilizer) treatment. While the S_0 treatment (Control) had the lowest length of siliqua of mustard (8.56 cm) which was statistically similar with S_1 (8.72 cm) treatment. Increase in siliqua length might due to availability of nutrient in adequate amount resulted in formation of photosynthesis, which promote metabolic activity, increase the cell division, ultimately increase the siliqua length plant^{-1}. Improved nutritional condition with sulphur fertilization would have attributed to this response as sulphur in consequent of chlorophyll, protein and many biologically active compounds which might have accelerated photosynthesis rate and growth.Islam *et al*. (2018) reported that the highest mustard siliqua length plant^{-1}was obtained from the combination of 120 kg N with 45 kg S ha^{-1}. Mohiuddin *et al.* (2011) reported that the length of siliquae of mustard was increased with increasing S levels significantly up to 16 kg S ha^{-1}.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 10. Effect of sulphur on length of silique of mustard (LSD $_{(0.05)}$ = 0.31).

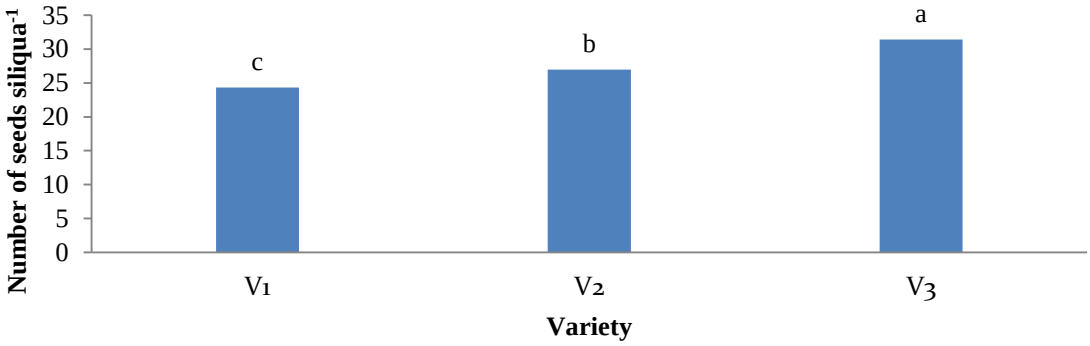
Combined effect of variety and sulphur

Different varieties along with sulphur application had shownsignificant effect on the siliqua length plant^{-1}of mustard. (Table 4). The experimental results showed that the V_3S_3 treatment combination had the highest siliqua length plant^{-1}of mustard (11.07 cm). The V_1S_0 treatment combination showed the lowest siliqua length plant^{-1}of mustard (7.47 cm) which was statistically similar with V_1S_1(7.97 cm) treatment combination.

4.2.3 Number of seeds siliqua^{-1}

Effect of variety

The number of seeds siliqua^{-1}of mustard varied significantly depending on the variety (Figure 11). According to the experimental findings the V_3 (BARI Sarisha-15) treatment had the highest number of seeds siliqua^{-1}of mustard (31.40). On the other hand, the V_1 (BARI Sarisha-9) treatment had the lowest number of seeds siliqua^{-1}of mustard (24.32). The differences of number of seeds siliqua^{-1}was due to the genetic makeup of the varieties. Similar result was observed by Lal *et al.* (2020) who reported that the variations in the genetic make-up of the variety, which is mostly controlled by inheritance, are the cause of variations in the number of seeds siliqua^{-1} among different varieties of mustard.

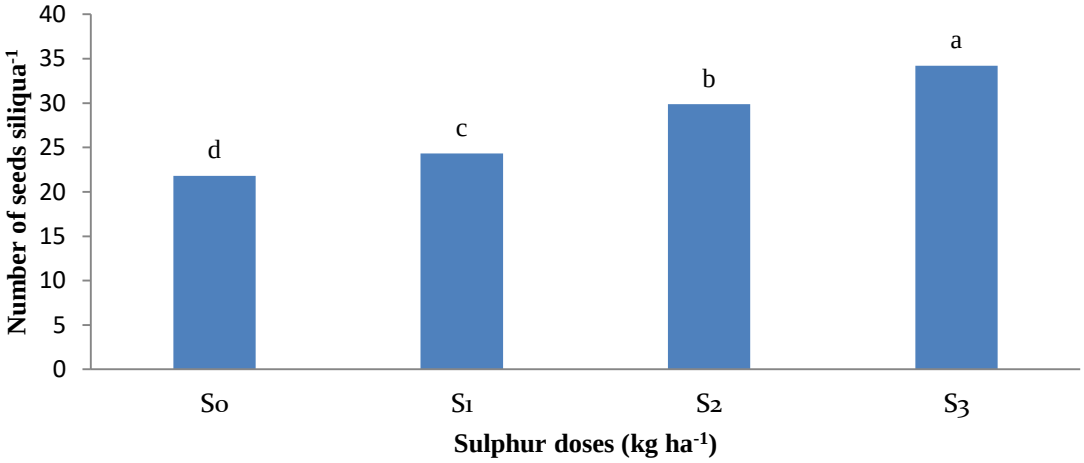


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 11. Effect of variety on number of seeds siliqua^{-1} of mustard (LSD $_{(0.05)}$ = 0.79).

Effect of sulphur

The number of seeds siliqua^{-1}of mustard was significantly affected by the various sulphur application doses (Figure 12). The results of the experiment showed that the S_3 treatment (25 % more than recommended dose of sulphur fertilizer) had the highest number of seeds siliqua^{-1}of mustard (34.21).TheS_0 (Control) treatment had the lowest number of seeds siliqua^{-1}of mustard (21.79).Increase in value of these yield contributing characters with higher levels of sulphur was due to the facts that the adequate sulphur was available during the entire period of crop growth for better vegetative growth and development of mustard plants. The result obtained from the present study was similar with the findings of Singh *et al*. (2018) who assessed that the application of sulphur proved to be beneficial in bringing about significant improvement in yield attributes of rajmash.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 12. Effect of sulphur on number of seeds siliqua^{-1} of mustard (LSD $_{(0.05)}$ = 0.90).

Combined effect of variety and sulphur

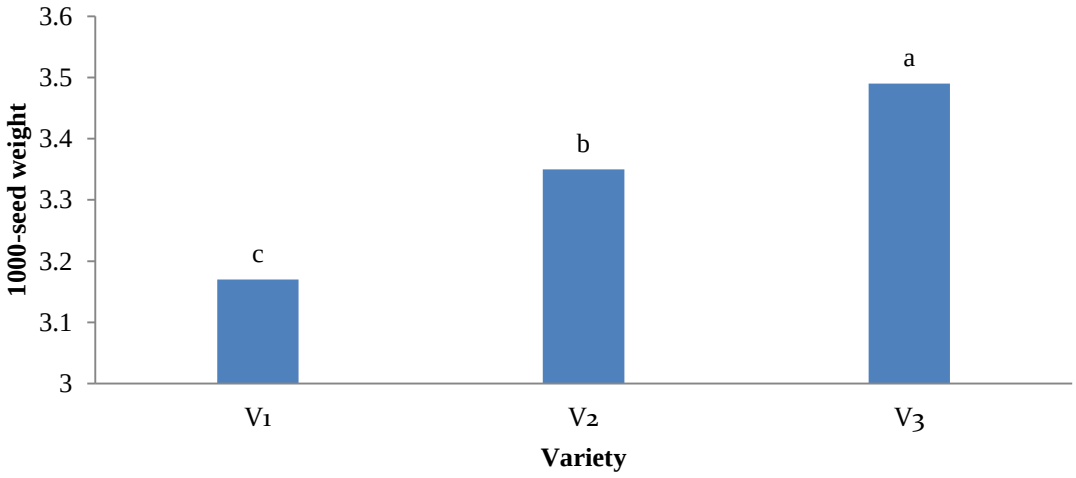
The number of mustard seeds siliqua^{-1} had been significantly affected by different varieties and sulphur application. (Table 4). According to the experimental findings, the V_3S_3 treatment combination had the highest number of seeds siliqua^{-1}of mustard

(40.34). The lowest number of seeds siliqua^{-1}(18.91) of mustard were seen with the V_1S_0 treatment combination which was statistically comparable to the V_1S_1 (20.07) treatment combination.

4.2.4 1000-seed weight

Effect of variety

The 1000-seed weight of mustard was significantly affected by different varieties. (Figure 13). The results of the experiment showed that the V_3 (BARI Sarisha-15) treatment had highest 1000-seed weight of mustard (3.49 g). The V_1 (BARI Sarisha-9) treatment had the lowest 1000-seed weight of mustard (3.17 g). The differences in 1000-seed weight among the various mustard varieties could be attributed to the traits of the mustard varieties and their genetic makeup. Similar result observed by Sarker *et al*. (2021) who reported that the 1000 seed weight of mustard varied from variety to variety and species to species.Mamun *et al.* (2014) also reported that among different varieties BARI Sarisha-13 had the highest 1000- seed weight (4.00 g) whereas the lowest (2.82 g) - in SAU Sarisha-3.

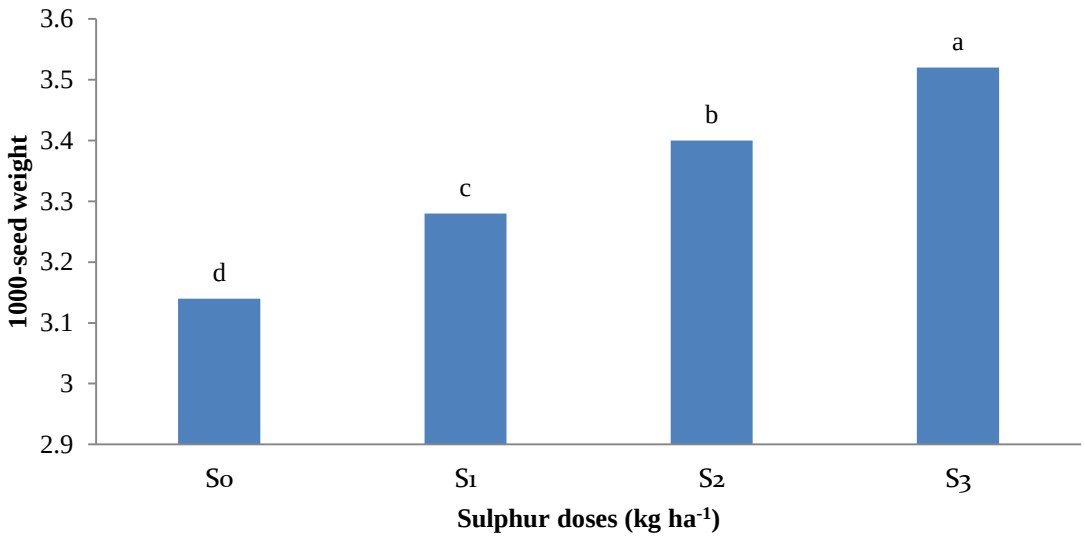


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 13. Effect of variety on 1000-seed weight of mustard (LSD $_{(0.05)}$ = 0.007).

Effect of sulphur

The different dose of sulphur application had shown significant effect on the 1000 seed weight of mustard (Figure 14). The experimental findings revealed that the S_3 treatment (25 % more than recommended dose of sulphur fertilizer*)* had the highest 1000-seed weight of mustard (3.52 g). The S_0 (Control) treatment, had the lowest1000-seed weight of mustard (3.14 g). The improved nutritional environment as a result of increased S supply might have favourably influenced the carbohydrate metabolism. This favourable effect led to increased translocation of photosynthates towards seeds resulting in the formation of bold seeds and increased seed weight. The result obtained from the present study was similar with the findings of Islam *et al*. (2018) who reported that the highest 1000-seed weight of rapeseed was obtained from the combined application of 120 kg N along with 45 kg S ha^{-1}.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 14. Effect of sulphur on 1000-seed weight of mustard (LSD $_{(0.05)}$ = 0.009).

Combined effect of variety and sulphur

The 1000 seed weight of mustard varied significantly depending on the variety and sulphur application. (Table 4). According to the experimental findings, the highest 1000 seed weight (3.81 g) was found in V_3S_3 treatment interaction. However, the lowest 1000

seed weight was indicated by the V_1S_0 treatment interaction (3.03 g) which was statistically similar with theV_1S_1(3.11 g) and V_2S_0 (3.14 g) treatment interaction.

Table 4. Combined effect of variety and different sulphur levels on number of silique plant^{-1}, length of siliqua, number of seeds siliqua^{-1} and 1000-seed weight of mustard.

Treatment combinations	Number of silique plant^{-1}	Length of siliqua (cm)	Number of seeds siliqua^{-1}	1000-seed weight (g)
V_1S_0	70.07 f	7.47 e	18.91 g	3.03 h
V_1S_1	75.33 ef	7.97 de	20.07 g	3.11 gh
V_1S_2	78.33 e	8.07 d	27.26 d	3.25 e-g
V_1S_3	81.67 de	8.17 d	31.02 b	3.29 d-f
V_2S_0	87.33 cd	8.47 d	22.17 f	3.14 f-h
V_2S_1	88.33 cd	8.47 d	23.58 ef	3.35 c-e
V_2S_2	91.47 c	9.07 c	30.80 bc	3.44 b-d
V_2S_3	99.33 b	9.33 bc	31.26 b	3.45 bc
V_3S_0	100.40 b	9.73 b	24.29 e	3.25 e-g
V_3S_1	100.67 b	9.73 b	29.36 c	3.37 b-e
V_3S_2	111.03 a	9.77 b	31.60 b	3.51 b
V_3S_3	116.33 a	11.07 a	40.34 a	3.81 a
$LSD_{(0.05)}$	7.22	0.54	1.59	0.15
CV(%)	4.65	3.58	3.40	2.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

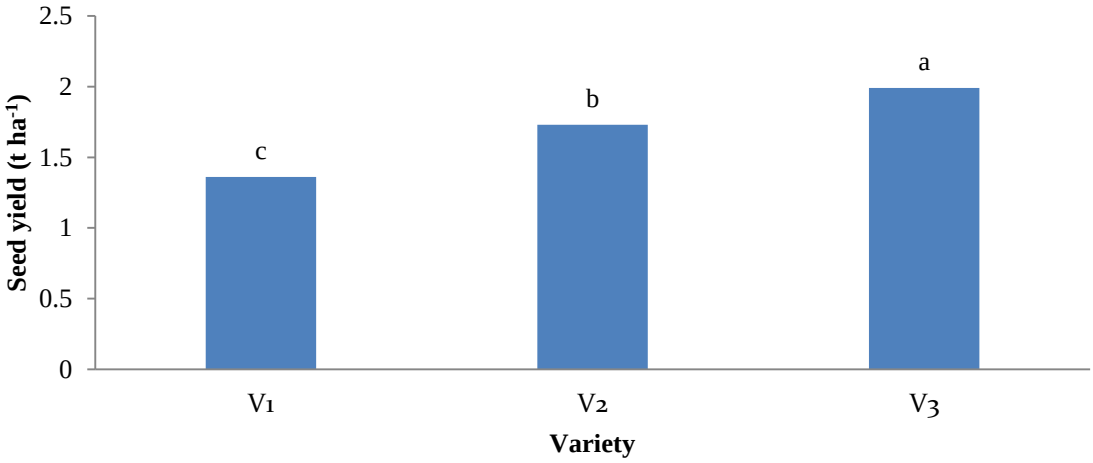
4.3 Yield characters

4.3.1 Seed yield (t ha^{-1})

Effect of variety

Mustard seed yield was significantly influenced by different varieties. (Figure 15). In this experiment result revealed that the V_3 (BARI Sarisha-15) treatment recorded the highest seed yield of mustard (1.99 t ha^{-1}). The V_1 (BARI Sarisha-9) treatment had the

lowest seed yield (1.36 t ha^{-1}). Different mustard varieties had different genetic makeup which affects the growth and yield among different kinds. The result obtained from the present study was similar with the findings of Priyanka *et al.* (2020) who reported that yield varies among different varieties and the maximum seed yield was observed in variety CS-58 (21.84 q ha^{-1}) than comparison to other varieties. Afroz *et al*. (2011) also observed that *cv*. BARI Sarisha-9 recorded significantly higher seed yield (1.54 t ha^{-1}) as compared to *cv*. BARI Sarisha-6 (1.41 t ha^{-1}).



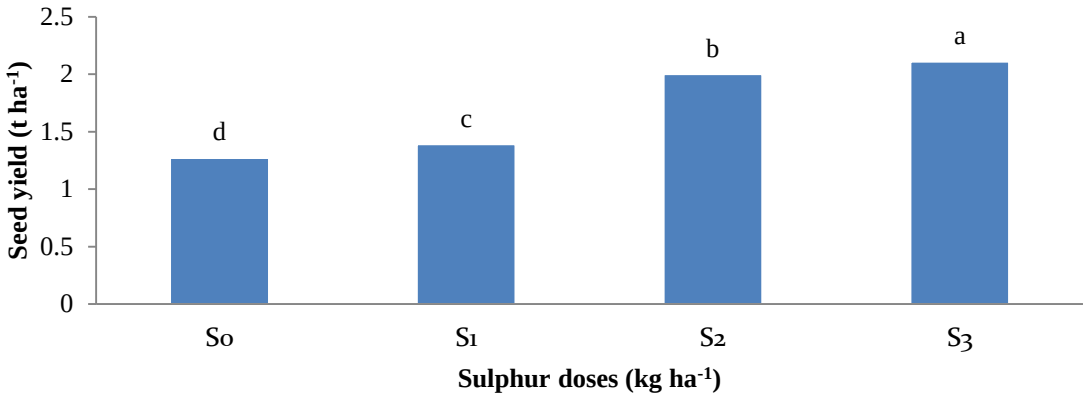
In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 15. Effect of variety on seed yield of mustard (LSD $_{(0.05)}$ = 0.07).

Effect of sulphur

The seed yield of mustard was significantly affected by the varied doses of sulphur application (Figure 16). The results of the experiment showed that the S_3 treatment (25 % more than recommended dose of sulphur fertilizer) had the highest seed yield of mustard (2.11 t ha^{-1}). Whereas the lowest seed yield of mustard (1.27 t ha^{-1}) was found in the S_0 (Control) treatment. The combination of a higher number of siliquae plant^{-1} and seeds siliqua^{-1} may have a significant impact on the increase in seed yield under adequate sulphur supply. This beneficial effect of sulfur application could be attributed to sulphur nutrition, which promotes cell multiplication, elongation, and expansion. Sulphur nutrition also improves chlorophyll synthesis, which in turn increases the effective area for photosynthesis. This results in a relatively greater amount of

photosynthates accumulating in the plant and their translocation, which reflects in terms of increased yield attributes of crops. Nayak *et al.* (2020) reported that the highest seed yield of mustard was found with the treatment where sulphur was applied at the rate of 60 kg ha^{-1}. Similar result was also observed by Ray *et al.* (2014) who reported that yield of mustard was increased with the increasing dose of sulphur from 0 to 60 kg ha^{-1}. Higher yield was obtained with 60 kg S ha^{-1} that resulted in 17.9% increase over control.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 16. Effect of sulphur on seed yield of mustard (LSD $_{(0.05)}$ = 0.008).

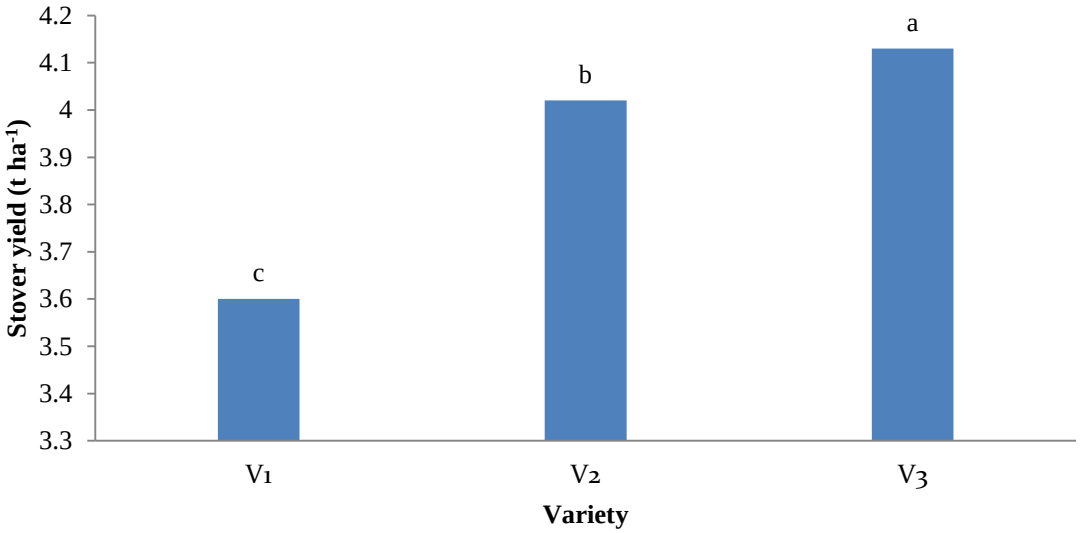
Combined effect of variety and sulphur

Depending on the variety and sulphur application, mustard seed yield varied significantly (Table 5). According to the experimental results, the V_3S_3 treatment combination (2.38 t ha^{-1}), which was statistically comparable to the V_3S_2 (2.37 t ha^{-1}) treatment interaction recorded the highest seed yield. TheV_1S_0 treatment combination indicated the lowest seed yield (0.95 t ha^{-1}).

4.3.2 Stover yield (t ha^{-1})

Effect of variety

The stover yield was significantly influenced by different mustard varieties (Figure 17). The results of the experiment indicated that the V_3(BARI Sarisha-15) treatment had the highest stover yield (4.13 t ha^{-1}). The V_1 treatment had the lowest stover yield (3.60 t ha^{-1}). Sultana *et al.* (2009) also found similar result with present study and reported that stover yield of mustards were varied with different varieties.



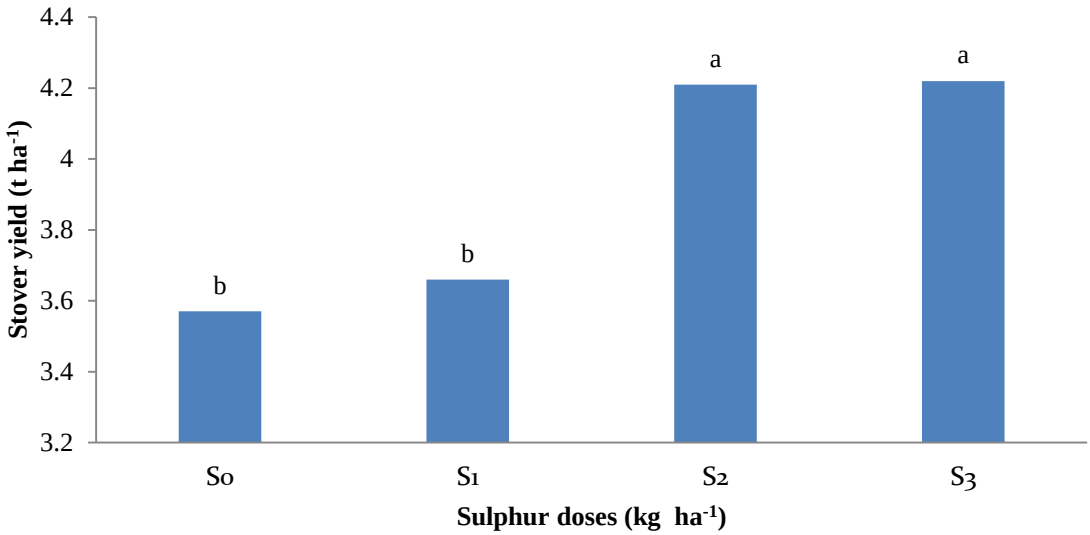
In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 17. Effect of variety on stover yield of mustard (LSD $_{(0.05)}$ = 0.08).

Effect of sulphur

The different doses of sulphur application had shown significant effect on the stover yield of mustard (Figure 18). The experimental findings showed that the S_3(25 % more than recommended dose of sulphur fertilizer) treatment recorded the highest stover yield (4.22 t ha^{-1}) which was statistically similar with S_2 (4.21 t ha^{-1}) treatment. The lowest stover yield was achieved with the S_0 treatment (3.57 t ha^{-1}) which was statistically similar with S_1 (3.66 t ha^{-1}) treatment. Stover yield is chiefly a product of growth parameters like plant height, number of branches and dry matter accumulation. So the increase in these characters as a result of sulphur fertilization resulted in increase

of straw yield of mustard. Singh *et al.* (2017) reported that the stover yield of mustard increased significantly up to 60 kg S ha^{-1} which was 51.1% higher than control.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 18. Effect of sulphur on stover yield of mustard (LSD $_{(0.05)}$ = 0.09).

Combined effect of variety and sulphur

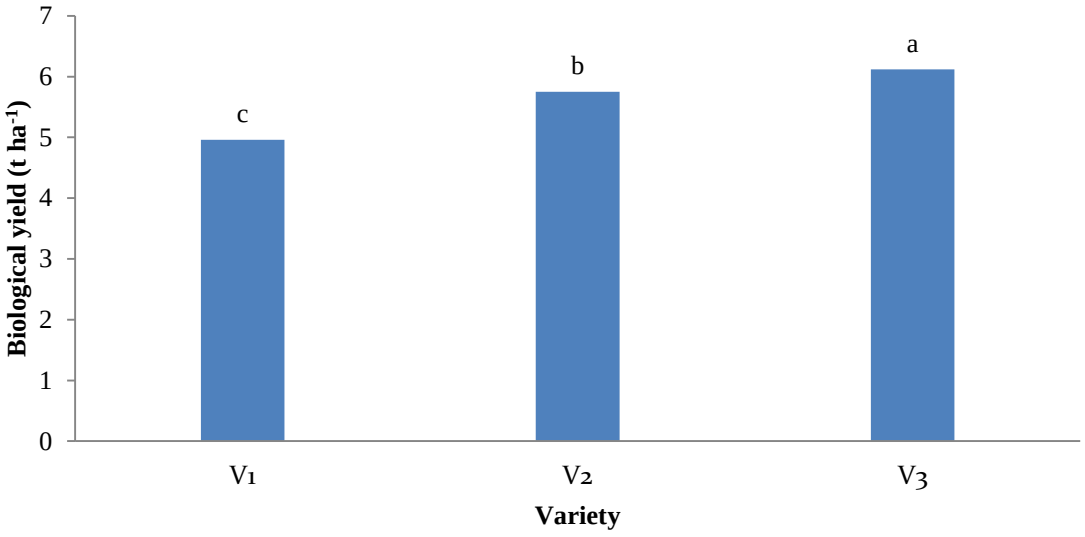
The stover yield of mustad varied significantly according to the combined effect of different varieties and levels of sulphur application. (Table 5). The highest stover yield (4.39 t ha^{-1}) was observed in V_3S_3 treatment combination which was statistically equal to the V_3S_2 (4.39 t ha^{-1}) treatment combination. Whereas the lowest stover yield (3.21 t ha^{-1}) was revealed by the V_1S_0 treatment interaction.

4.3.3 Biological yield (t ha^{-1})

Effect of variety

Different mustard varieties had significant effect on the biological yield (Figure 19). The experimental findings showed that the V_3(BARI Sarisha-15) treatment recorded the highest biological (6.12 t ha^{-1}).The least biological yield was found in V_1(BARI Sarisha-9) treatment (4.96 t ha^{-1}).The variation of biological yield by different varieties might be due to the contribution of cumulative favourable effects of the crop

characteristics viz., seed and stover yield of the crop.Tobe *et al.* (2013) also found similar result which supported the present finding and reported that the variation in biological yield differ among cultivars of *B. napus*. Singh *et al.* (2002) reported that biological yield was significantly higher in mustard *cv.* Laxmi (1370 kg ha^{-1}) over *cv.* BJH-1 (1190 kg ha^{-1}).



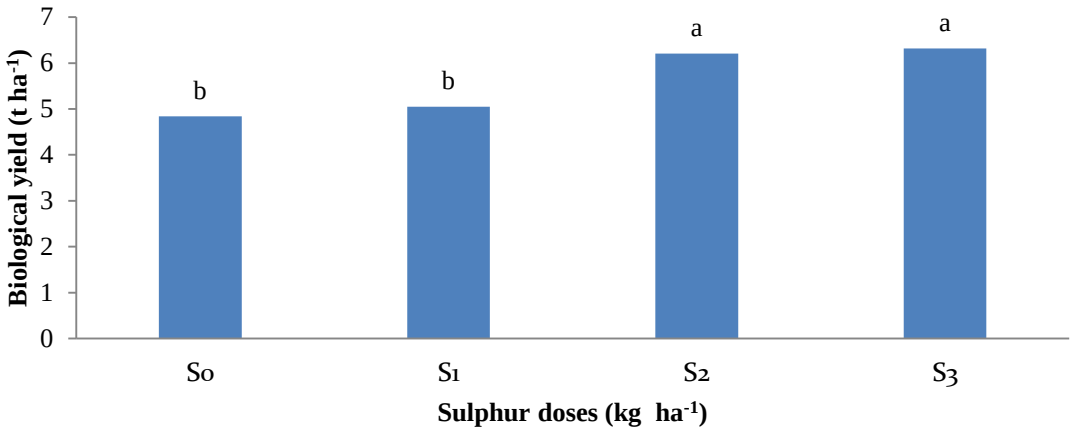
In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 19. Effect of variety on biological yield of mustard (LSD $_{(0.05)}$ = 0.25).

Effect of sulphur

The biological yield of mustard was significantly affected by the various doses of sulphur application (Figure 20). The results of the experiment demonstrated that the highest biological yield (6.32 t ha^{-1}) was obtained by the S_3 (M25 % more than recommended dose of sulphur fertilizer) treatment, which was statistically comparable with the S_2(6.21 t ha^{-1}) treatment. The S_0 (Control) treatment resulted in the lowest biological yield (4.84 t ha^{-1}) which was statistically comparable with the S_1(5.05 t ha^{-1}) treatment. The substantial increase in biological yield due to application of higher doses of sulphur might be due to favourable effect of sulphur on growth attributes like increased dry matter accumulation per plant and its subsequent translocation towards sink.Singh *et al*. (2019) showed that biological yield (77.86 q ha^{-1}) was significantly higher under RDF+ 40 kg S ha^{-1} through (Single Super Phosphate) SSP.Mohiuddin *et*

al. (2011) also reported that the biological yield of mustard increased with increasing S levels significantly up to 16 kg S ha^{-1}.



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 20. Effect of sulphur on biologcal yield of mustard (LSD $_{(0.05)}$ = 0.28).

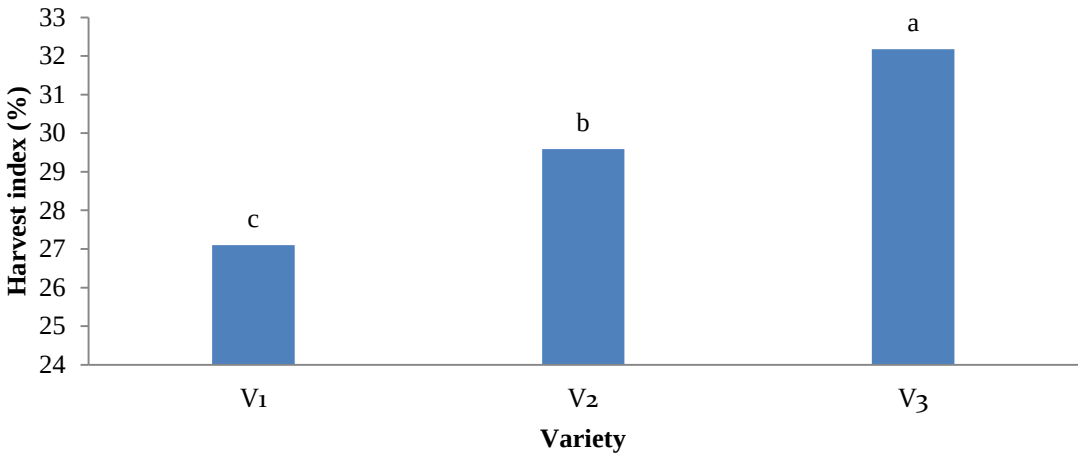
Combined effect of variety and sulphur

Different varieties along with sulphur application had shown significant effect on the biological yield of mustard. (Table 5). The V_3S_3 treatment combination had the highest biological yield (6.77 t ha^{-1}), which was statistically equal to the V_3S_2(6.76 t ha^{-1}), V_2S_3 (6.68 t ha^{-1}) andV_2S_2(6.52 t ha^{-1}) treatment combination. Whereas the V_1S_0 treatment combination recorded the lowest biological yield (4.16 t ha^{-1}).

4.3.4 Harvest index (%)

Effect of variety

Mustard varieties significantly influenced harvest index (Figure 21). The results of the investigation showed that the V_3 (BARI Sarisha-15) treatment recorded the highest harvest index (32.18 %). The V_1 (BARI Sarisha-9) treatment had the lowest harvest index (27.10 %). Due to genetic diversity, the harvest index varied greatly between varieties. Thakur *et al.* (2021) reported that harvest index of mustard was significantly influenced by different varieties and maximum harvest index (36.95) was observed in T_2 [genotype 45S35] treatment comparable to other treatments.

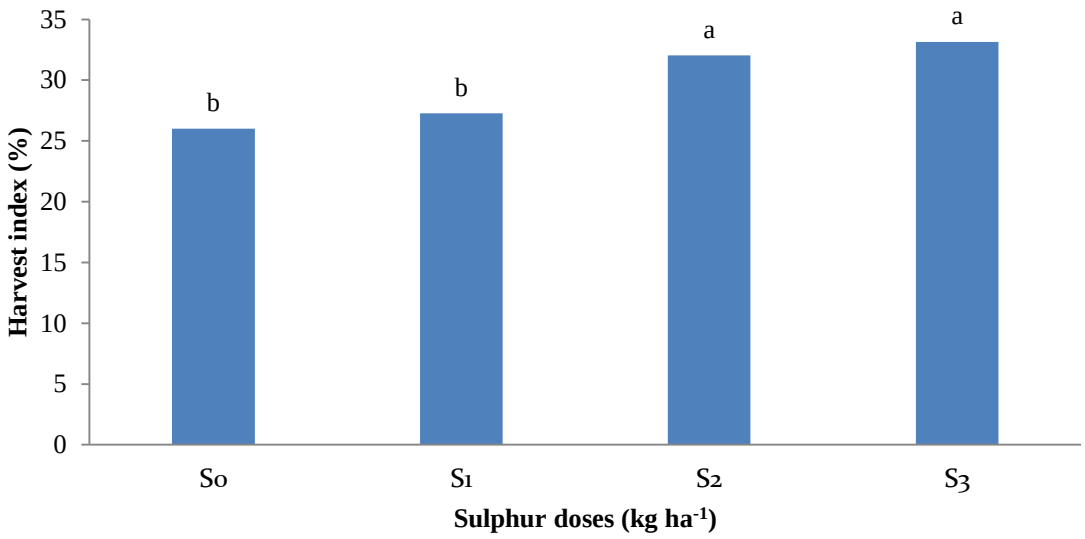


In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15.

Figure 21. Effect of variety on harvest index of mustard (LSD $_{(0.05)}$ = 1.30).

Effect of sulphur

The different doses of sulphur application had significant effect on the harvest index of mustard (Figure 22). The experimental findings showed that the S_3 (25 % more than recommended dose of sulphur fertilizer) treatment, which was statistically equal to the S_2 (32.05 %) treatment, had the highest harvest index (33.16 %). Although statistically equal to the S_1 (27.28 %) treatment, the S_0 (Control) treatment recorded the lowest harvest index (26.00 %). The higher harvest index could be attributed to the higher dry matter production and it's accumulation in reproductive parts, higher number of siliqua plant^{-1}, seeds siliqua, 1000-seed weight, seed yield per plant and seed yield per plot.Verma *et al*. (2012) also found similar result which supported the present finding and reported that the application of fertilizers 120 kg N + 45 kg S ha^{-1} in mustard gave significantly higher harvest index and protein content (%) than other levels of fertilizers (control, 40 N + 15 S and 80 N + 30 S kg ha^{-1}).



In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0 = control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Figure 22. Effect of sulphur on harvest index of mustard (LSD $_{(0.05)}$ = 1.51).

Combined effect of variety and sulphur

The harvest index of mustard was significantly influenced by different variety and sulphur application. (Table 5). The highest index yield (35.16 %) was recorded by the V_3S_3 treatment interaction, which was statistically equal to the V_3S_2 (35.05 %) and V_2S_3 (33.53 %) treatment combination. The lowest harvest index (22.84 %) was recorded by the V_1S_0 treatment combination, which was statistically equal to the V_1S_1 (24.79 %) treatment combination.

Table 6. Combined effect of variety and fertilizer levels on seed, stover, biological yield and harvest index of mustard.

Treatment combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1S_0	0.95 g	3.21 f	4.16 e	22.84 g
V_1S_1	1.19 f	3.61 de	4.80 d	24.79 fg
V_1S_2	1.60 d	3.74 b-d	5.34 bc	29.96 cd
V_1S_3	1.70 cd	3.82 bc	5.52 bc	30.80 c
V_2S_0	1.41 e	3.66 cd	5.07 cd	27.81 de
V_2S_1	1.22 f	3.49 e	4.71 d	25.90 ef
V_2S_2	2.03 b	4.49 a	6.52 a	31.13 bc
V_2S_3	2.24 a	4.44 a	6.68 a	33.53 ab
V_3S_0	1.45 e	3.85 b	5.30 bc	27.36 d-f
V_3S_1	1.76 c	3.89 b	5.65 b	31.15 bc
V_3S_2	2.37 a	4.39 a	6.76 a	35.05 a
V_3S_3	2.38 a	4.39 a	6.77 a	35.16 a
$LSD_{(0.05)}$	0.14	0.17	0.49	2.62
CV(%)	5.19	2.55	5.21	5.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15, F_0 = control, F_1= 25 % less than recommended dose of sulphur fertilizer (RDS), F_2= RDS and F_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm SAU, Dhaka to study the systems of mustard intensification as influenced by variety and sulphur, during the period from October 2020 to February 2021in *Rabi* season. The experiment was consisted of two factors and followed randomized complete block design with three replications. Factor A: Mustard varieties (3) *viz;* V_1 = BARI Sarisha-9, V_2 = BARI Sarisha-14 andV_3 = BARI Sarisha-15, and Factor B: Different doses of sulphur (4) *viz;* S_0 = Control, S_1= 25 % less than recommended dose of sulphur fertilizer (RDS), S_2= RDS and S_3= 25 % more than recommended dose of sulphur fertilizer (RDS). Data on different parameters were collected for assessing results for the experiment. The experimental results revealed that different varieties and sulphur application significantly influenced the growth, yield contributing characteristics and yield of mustard. In case of different mustard varieties, the lowest seed yield (1.36 t ha^{-1}) was obtained fromV_1 treatment (BARI Sarisha-9). Whereas cultivating of BARI sarisha-15 (V_3) variety gave the highest number of siliqua $plant^{-1}$ (107.11), length of siliqua (10.08 cm), number of seeds $siliqua^{-1}$ (31.40), 1000-seed weight (3.49 g), seed yield (1.99 t ha^{-1}), stover yield (4.1399 t ha^{-1}), biological yield (6.12 t ha^{-1}) and harvest index (32.18 %). In case of different doses of sulphur application, the seed yield ranges between (1.27-2.11t ha^{-1}). The highest seed yield (2.11 t ha^{-1}) was recorded in S_3 (25 % more than recommended dose of sulphur fertilizer) treatment which was due to enhanced yield attributes like siliqua $plant^{-1}$ (99.11), length of siliqua (9.52cm), number of seeds siliqua^{-1} (34.21) and 1000-seed weight (3.52 g).

In case of combination, cultivation of BARI Sarisha-15 (V_3) along with 25 % more than recommended dose of sulphur fertilizer (S_3) affected plant growth and yield-contributing characteristics, leading to the maximum seed yield (2.38 t ha^{-1}) than compared to other treatment combination. However, V_2S_3 (2.24 t ha^{-1}), V_3S_2 (2.37 t ha^{-1}) and V_3S_3 (2.38 t ha^{-1}) showed statistically similar seed yield ha^{-1}.

As a result, it was proposed that cultivating BARI Sarisha-15 in conjunction with the recommended dose of sulphur fertilizer (V_3S_2) would help to influence plant growth and increase its ability to enhance better mustard yield production using the SMI technique.

Recommendations

Further experiment may be conducted on system of mustard intensification (SMI) with different variety and different doses of macro nutrients for higher productivity of mustard under different agro-climatic condition in Bangladesh.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	**Characteristics**
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

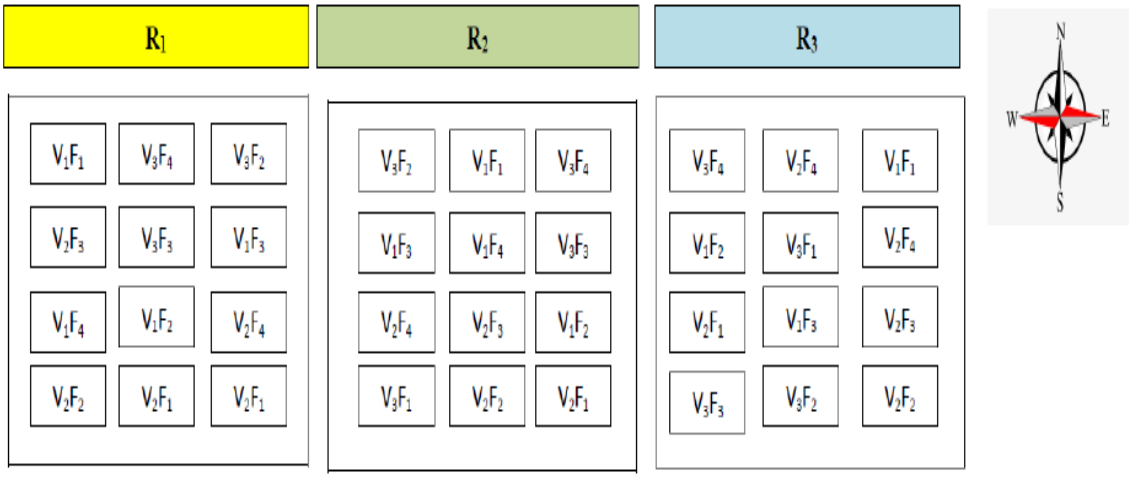
Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III.Monthly meteorological information during the period from October, 2019 to February 2020.

Year	Months	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	October	31.40	23.90	78.00	54.00
	November	29.50	19.80	55.00	00
	December	28.60	19.10	49.00	00
2020	January	25.40	13.10	42.00	00
	February	25.80	140	36.00	7.70

(Source : Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout of the experimental field.



Here, R= Replication, V_1 = BARI sarisha-9, V_2 = BARI sarisha-14, V_3 = BARI sarisha-15, F_0 = control, F_1= 25 % less than recommended dose of sulphur fertilizer (RDS), F_2= RDS and F_3= 25 % more than recommended dose of sulphur fertilizer (RDS).

Appendix V. Analysis of variance of the data of plant height of mustard as influenced by variety, sulphur doses and their combination at different days after transplanting.

Mean square values of plant height at					
Sources	Df	30 DAT	45 DAT	60 DAT	At harvest
Replication (R)	2	0.333	14.083	17.33	0.36
Variety (V)	2	129.227*	740.439*	1541.82*	1654.25*
Sulphur (S)	3	27.313*	56.730*	203.16*	200.27*
V×S	6	11.503*	11.253*	29.45*	33.82*
Error	22	1.788	4.083	10.79	11.39
Total	35				

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of number of branches plant^{-1} of mustard as influenced by variety, sulphur doses and their combination at differentdays after transplanting.

Mean square values of number of branches plant^{-1}					
Sources	Df	30 DAT	45 DAT	60 DAT	At harvest
Replication (R)	2	0.0052	2.083	6.750	5.333
Variety (V)	2	0.7557*	49.625*	470.954*	432.264*
Sulphur (S)	3	10.0724*	174.332*	383.103*	147.948*
V×S	6	0.6105*	16.790*	96.581*	71.794*
Error	22	0.0034	1.356	5.295	1.515
Total	35				

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of above ground dry matter weight of mustard as influenced by variety, sulphur doses and their combination at different days after transplanting..

Mean square values of above ground dry matter weight at					
Sources	Df	30 DAT	45 DAT	60 DAT	At harvest
Replication (R)	2	0.00067	0.1200	10.083	27.00
Variety (V)	2	0.05333*	58.5992*	610.989*	6697.52*
Sulphur (S)	3	0.02369*	3.7733*	364.373*	497.33*
V×S	6	0.00399*	2.5054*	28.628*	71.91*
Error	22	0.00042	0.0836	4.992	8.64

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of siliqua plant-^{1}, length of siliqua (cm), number of seeds siliqua^{-1} and 1000 seeds weight (g) of mustard as influenced by variety, sulphur doses and their combination.

Sources	Df	Mean square values of			
		Number of siliqua plant^{-1}	Length of siliqua	Number of seeds siliqua^{-1}	1000 seeds weight
Replication (R)	2	2.730E-27	0.0300	0.333	0.00030
Variety (V)	2	2838.12*	14.0377*	153.752*	0.29890*
Sulphur (S)	3	314.095*	1.6051*	279.823*	0.23593*
V×S	6	17.0868*	0.2864*	11.661*	0.02243*
Error	22	18.1818	0.1027	0.879	0.00857

*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of seed yield, stover yield, biological yield and harvest index of mustard as influenced by variety, sulphur doses and their combination.

Sources	Df	Mean square values of			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	1.20070	0.95790	4.24390	77.504
Variety (V)	2	1.60830*	1.06843*	5.28740*	110.999*
Sulphur (S)	3	0.05770*	0.11533*	0.28160*	5.222*
V×S	6	0.00771*	0.01000*	0.08547*	2.417*
Error	22				

*: Significant at 0.05 level of probability

PLATES

Plate 1. Land preparation of the experimental field.

Plate 2. Seedling transplanting to the experimental field.

Plate 3. Data collection.

Plate 4. Picture showing flower initiation of the mustard crop.