INTERACTION EFFECT OF SULPFUR AND BORON ON THE GROWTH, YIELD, CHEMICAL COMPOSITION AND OIL CONTENT OF MUSTARD (SAU SARISHA-1)

By

RAZZAK HOSSAIN

REGISTRATION. No. 01161

A Thesis

Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

Library

MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE

Semester: January-June, 2008

Approved by:

.....
(Prof. Dr. Md. Nurul Islam)
Supervisor

.....
(Prof. Dr. Sirajul Hoque)
Co-supervisor

.....
A.T. M. Shamsuddoha
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

PABX: +88029144270-9
Fax: +88029112649
www.sau.edu.bd

Ref:

Date: .....

CERTIFICATE

This is to certify that the thesis entitled "INTERACTION EFFECT OF SULPHUR AND BORON ON THE GROWTH, YIELD, CHEMICAL COMPOSITION AND OIL CONTENT OF MUSTARD (***Brassica campestris*** L.)" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) IN SOIL SCIENCE, embodies the result of a piece of *bonafide* research work carried out by RAZZAK HOSSAIN, Registration No. 01161 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 by him.

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

Dated:
Place:Dhaka, Bangladesh

Prof. Dr. Md. Nurul Islam
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Library

ACKNOWLEDGEMENTS

All the praises, gratitude and thanks are due to the omniscient, omnipresent and omnipotent Allah who enabled me to complete this thesis work successfully for my MS degree.

I wish to express my sincere appreciation and profound gratitude and best regards to my reverend supervisor, Prof. Dr. Md. Nurul Islam, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 for his scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.

I deem it a proud privilege to acknowledge my gratefulness, boundless gratitude and best regards to my respectable co-supervisor Prof. Dr. Sirajul Hoque, Department of Soil, Water and Environment, Dhaka University, Dhaka for his valuable advice, constructive criticism and factual comments in upgrading the research work.

It is a great pleasure and privilege to express my profound gratitude and sincere regards to Associate Professor Mr. A. T. M. Shamsuddoha, Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for his help, heartiest co-operation, efficient guidance, valuable advice, constructive criticism and facilities and supports needed to undertake this research work.

Special appreciation and warmest gratitude are extended to my esteemed teachers Professor Dr. Gopi Nath Chandra Sutradhar, Professor Dr. Alok Kumer Paul, Associate Prof. Dr. Md. Asaduzzaman Khan, Associate Prof. Mst. Afrose Jahan and Assistant Prof. Md. Mosharraf Hossain, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka who provided creative suggestions, guidance and constant inspiration from the beginning to the completion of the research work. Their contribution, love and affection would persist in my memory for countless days.

I owe a lot to Professor Kamal Uddin Ahmed, Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka for his great help to determine oil content of mustard.

Again I would like to expresse my cordial thanks to lecturers Md. Saiful Islam Bhuiyan, Md. Issak, Saikat Chowdhury, Jharna Rani Sarkar, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka for their encouragement and active co-operation during the entire period of the research. I wish to express my cordial thanks to Departmental and field staffs for their active help during the experimental period. Sincere appreciation goes to SAURES for partial financial support to complete the field research.

I want to give thanks to my all classmates and friends for their active encouragement and inspiration; personal acknowledgement are to Dilruba, Arif, Roni, Momin, Iqbal, Mamun, Hasan, Sharif, Asad.

I expresses my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my father Md. Abdus Samad, mother Mst. Sahida Akter, my uncles whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of my higher study and also pleasant to my sisters Salma and Nazma and all cousins.

Dated: June, 2008 The Author

Place: Dhaka, Bangladesh.

ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka during the period from November 2007 to March 2008 to study the effect of sulphur and boron alone and combined on the growth, yield, chemical composition and oil content of SAU Sarisha -1 (*Brassica campestris* L.). The experiment included four levels of sulphur viz., 0, 15, 25 and 35 kg S ha^{-1} and four levels of boron viz., 0, 1, 2 and 4 kg B ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. Sulphur showed significant effect on yield and yield attributes of mustard except 1000-seed weight. Application of sulphur @ 25 kg ha^{-1} produced the highest seed yield, plant height, siliqua $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000-seed weight, stover yield. In all the cases lower response was found from the control treatment. Boron fertilizer also had significant effect on yield and yield attributes of rapeseed except 1000-seed weight. Application of boron @ 2 kg ha^{-1} gave the highest seed yield, plant height, pods $plant^{-1}$, seeds pod^{-1}, 1000-seed weight, stover yield but in all cases the lower response was found from the control treatment. Sulphur @ 25 kg ha^{-1} was found statistically superior to all other treatments. Sulphur in combination with boron showed significant effect on yield and yield attributes of mustard. Sulphur @ 25 kg and boron @ 2 kg ha^{-1} resulted the highest seed yield, plant height, stover yield, protein content, oil content and total uptake of S and B by mustard. On the other hand in all the cases lower response was found from the control treatment. The addition of S and B not only increased the yield but also protect the soil from total exhaustion of nutrients.

LIST OF ABBRIVIATIONS

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
@	At the rate of
B	Boron
cm	Centimeter
$CuSO_4.5H_2O$	Green vitriol
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
DAS	Days After Sowing
DMRT	Duncan's Multiple Range Test
e.g.	As for example
et al	and others
g	Gram
i.e.	that is
K	Potassium
kg	Kilogram
kg ha^{-1}	Kg per hectare
K	Potassium
LSD	Least Significant Difference
S	Sulphur
TSP	Triple Super Phosphate
m	Meter
MP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
P	Phosphorus
NS	Not Significant
OM	Organic matter
pH	Hydrogen ion concentration
^0C	Degree Celsius
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare

LIST OF CONTENTS

CHAPTER	TITLE		PAGES
	ACKNOWLEDGEMENT		**i**
	ABSTRACT		**iii**
	LIST OF ABBREVIATIONS		**iv**
	LIST OF CONTENTS		**v**
	LIST OF TABLES		**xi**
	LIST OF FIGURES		**xiii**
	LIST OF APPENDICES		**xiv**
1	**INTRODUCTION**		**1**
2	**REVIEW OF LITERATURE**		**6**
	2.1	Effect sulphur on mustard	6
	2.2	Effect of boron on crop	18
	2.3	Interaction effect sulphur and boron on mustard	26
3	**MATERIALS AND METHODS**		**27**
	3.1	**Experimental site and soil**	**27**
	3.2	**Climate**	**30**
	3.3	**Seeds and variety**	**30**
	3.4	**Design and layout of the experiment**	**30**
	3.5	**Collection and processing of composite soil sample**	**34**
	3.6	**Land preparation**	**34**
	3.7	**Application of fertilizers**	**34**
	3.8	**Seed sowing**	**35**
	3.9	**Weeding and thinning**	**35**
	3.10	**Irrigation**	**35**
	3.11	**Pest management**	**35**
	3.12	**Harvesting and threshing**	**36**
	3.13	**Collection of experimental data**	**36**
	3.13.1	Plant height	37
	3.13.2	Number of primary branch per plant	37
	3.13.3	Number of pod plant^{-1}	37
	3.13.4	Number of seed pod^{-1}	37
	3.13.5	Pod length	37
	3.13.6	Thousand seed weight	38
	3.13.7	Grain yield	38
	3.13.8	Stover yield	38
	3.14	**Chemical analysis of the plant and soil samples**	**38**
	3.14.1	Plant Sample analysis	38
	3.14.1.a	Phosphorous	38
	3.14.1b	Potassium	38
	3.14.1c	Sulphur	39
	3.14.1d	Nitrogen	39
	3.14.2	**Soil sample analysis**	**39**
	3.14.2.a	Organic carbon	39
	3.14.2.b	Organic matter	40

LIST OF CONTENTS (Contd.)

CHAPTER		TITLE	PAGES
	3.14.2.c	Total nitrogen	40
	3.14.2.d	Available phosphorous	40
	3.14.2.e	Available potassium	40
	3.14.2.f	Available sulphur	40
	3.14.3	Available boron	41
	3.14.4	Soil p^H	41
	3.15	**Methods for seed analysis**	**41**
	3.15.1	**Protein content**	**41**
	3.15.2	**Oil content**	**41**
	3.16	**Total uptake of nutrient (kg ha^{-1})**	**42**
	3.17	**Statistical analysis**	**42**
4		**RESULTS AND DISCUSSIONS**	**43**
	4.1	**Plant height (cm)**	**43**
	4.1.1	Effect of sulphur on plant height of mustard	43
	4.1.2	Effect of boron on plant height of mustard	44
	4.1.3	Interaction effect of sulphur and boron on plant height of mustard	45
	4.2	**No. of branches $plant^{-1}$**	**47**
	4.2.1	Effect of sulphur on no. of branches $plant^{-1}$	47
	4.2.2	Effect of boron on no. of branches $plant^{-1}$	47
	4.2.3	Interaction effect of sulphur and boron on no. of branches $plant^{-1}$	47
	4.3	**No. of pods $plant^{-1}$**	**48**
	4.3.1	Effect of sulphur on no. of pods $plant^{-1}$	48
	4.3.2	Effect of boron on no. of pods $plant^{-1}$	48
	4.3.3	Interaction effect of sulphur and boron on no. of pods $plant^{-1}$	48
	4.4	**No. of seeds pod^{-1}**	**49**
	4.4.1	Effect of sulphur on no. of seeds pod^{-1}	49
	4.4.2	Effect of boron on no. of seeds pod^{-1}	49
	4.4.3	Interaction effect of sulphur and boron on no. of seeds pod^{-1}	49
	4.5	**Pod length**	**50**
	4.5.1	Effect of sulphur on pod length of mustard	50
	4.5.2	Effect of boron on pod length of mustard	50
	4.5.3	Interaction effect of sulphur and boron on pod length of mustard	50
	4.6	**Weight of 1000-seed**	**51**
	4.6.1	Effect of sulphur on weight of 1000-seed of mustard	51

4.6.2	Effect of boron on weight of 1000-seed of mustard	51
4.6.3	Interaction effect of sulphur and boron on weight of 1000-seed of mustard	52
4.7	**Grain yield**	**52**
4.7.1	Effect of sulphur on grain yield of mustard	52
4.7.2	Effect of boron on grain yield of mustard	53
4.7.3	Interaction effect of sulphur and boron on grain yield of mustard	53
4.8	**Stover yield**	**55**
4.8.1	Effect of sulphur on stover yield of mustard	55
4.8.2	Effect of boron on stover yield of mustard	55
4.8.3	Interaction effect of sulphur and boron on stover yield of mustard	55
4.9	**Total nitrogen content in mustard stover**	**56**
4.9.1	Effect of sulphur on nitrogen content in mustard stover	56
4.9.2	Effect of boron on nitrogen content in mustard stover	56
4.9.3	Interaction effect of sulphur and boron on nitrogen content in mustard stover	56
4.10	**Total phosphorus content in mustard stover**	**56**
4.10.1	Effect of sulphur on phosphorus content in mustard stover	56
4.10.2	Effect of boron on phosphorus content in mustard stover	57
4.10.3	Interaction effect of sulphur and boron on phosphorus content in mustard stover	57
4.11	**Total potassium content in mustard stover**	**58**
4.11.1	Effect of sulphur on potassium content in mustard stover	58
4.11.2	Effect of boron on potassium content in mustard stover	59
4.11.3	Interaction effect of sulphur and boron on potassium content in mustard stover	59

4.12	**Total sulphur content in mustard stover**	**59**
4.12.1	Effect of sulphur on sulphur content in mustard stover	59
4.12.2	Effect of boron on sulphur content in mustard stover	59
4.12.3	Interaction effect of sulphur and boron on sulphur content in mustard stover	60
4.13	**Total boron content in mustard stover**	**61**
4.13.1	Effect of sulphur on boron content in mustard stover	61
4.13.2	Effect of boron on boron content in mustard stover	61
4.13.3	Interaction effect of sulphur and boron on boron content in mustard stover	61
4.14	**Total nitrogen content in mustard seed**	**63**
4.14.1	Effect of sulphur on nitrogen content in mustard seed	63
4.14.2	Effect of boron on nitrogen content in mustard seed	63
4.14.3	Interaction effect of sulphur and boron on nitrogen content in mustard seed	63
4.15	**Total phosphorus content in mustard seed**	**64**
4.15.1	Effect of sulphur on phosphorus content in mustard seed	64
4.15.2	Effect of boron on phosphorus content in mustard seed	65
4.15.3	Interaction effect of sulphur and boron on phosphorus content in mustard seed	65
4.16	**Total potassium content in mustard seed**	**65**
4.16.1	Effect of sulphur on potassium content in mustard seed	65
4.16.2	Effect of boron on potassium content in mustard seed	66
4.16.3	Interaction effect of sulphur and boron on potassium content in mustard seed	66

4.17	**Total sulphur content in mustard seed**	**66**
4.17.1	Effect of sulphur on sulphur content in mustard seed	66
4.17.2	Effect of boron on sulphur content in mustard seed	67
4.17.3	Interaction effect of sulphur and boron on sulphur content in mustard seed	67
4.18	**Total boron content in mustard seed**	**68**
4.18.1	Effect of sulphur on boron content in mustard seed	68
4.18.2	Effect of boron on boron content in mustard seed	68
4.18.3	Interaction effect of sulphur and boron on boron content in mustard seed	68
4.19	**Protein content in mustard seed**	**70**
4.19.1	Effect of sulphur on protein content in mustard seed	70
4.19.2	Effect of boron on protein content in mustard seed	70
4.19.3	Interaction effect of sulphur and boron on protein content in mustard seed	70
4.20	**Oil content in mustard seed**	**71**
4.20.1	Effect of sulphur on oil content in mustard seed	71
4.20.2	Effect of boron on oil content in mustard seed	71
4.20.3	Interaction effect of sulphur and boron on oil content in mustard seed	72
4.21	**Total uptake of sulphur by mustard**	**73**
4.21.1	Effect of sulphur on total uptake of sulphur by mustard	73
4.21.2	Effect of boron on total uptake of sulphur by mustard	73
4.21.3	Interaction effect of sulphur and boron on total uptake of sulphur by mustard	73
4.22	**Total uptake of boron by mustard**	**74**
4.22.1	Effect of sulphur on total uptake of boron by mustard	74

	4.22.2	Effect of boron on total uptake of boron by mustard	74
	4.22.3	Interaction effect of sulphur and boron on total uptake of boron by mustard	74
	4.23	**Effect of sulphur on organic carbon content, nutrient status and p^H of the post harvest soil**	**75**
	4.23.1	Organic carbon	75
	4.23.2	Total nitrogen	76
	4.23.3	Available phosphorus	76
	4.23.4	Available potassium	76
	4.23.5	Available sulphur	77
	4.23.6	Available boron	77
	4.23.7	p^H	77
	4.24	**Effect of sulphur on organic carbon content, nutrient status and p^H of the post harvest soil**	**78**
	4.24.1	Organic carbon	78
	4.24.2	Total nitrogen	79
	4.24.3	Available phosphorus	79
	4.24.4	Available potassium	79
	4.24.5	Available sulphur	80
	4.24.6	Available boron	81
	4.24.7	p^H	81
	4.25	**Interaction effect of sulphur and boron on organic carbon content, nutrient status and p^H of the post harvest soil**	**81**
	4.25.1	Organic carbon	81
	4.25.2	Total nitrogen	82
	4.25.3	Available phosphorus	82
	4.25.4	Available potassium	82
	4.25.5	Available sulphur	84
	4.25.6	Available boron	84
	4.25.7	p^H	84
5		**SUMMARY AND CONCLUSION**	**85**
6		**REFERENCES**	**90**
		APPENDICES	**105**

LIST OF TABLES

TABLE	TITLES OF TABLES	PAGES
3.1	Morphological characteristics of experimental field	29
3.2	Physical and chemical properties of the experimental soil	29
4.1	Effect of sulphur on yield growth parameters of mustard	44
4.2	Effect of boron on yield growth parameters of mustard	45
4.3	Interaction effect of sulphur and boron on yield growth parameters of mustard	46
4.4	Effect of sulphur on yield and yield contributing characters of mustard	51
4.5	Effect of boron on yield and yield contributing characters of mustard	52
4.6	Interaction effect of sulphur and boron on yield and yield contributing characters of mustard	54
4.7	Effect of sulphur on total N, P, K, S and B contents of mustard stover	58
4.8	Effect of boron on total N, P, K, S and B contents of mustard stover	60
4.9	Interaction effect of sulphur and boron on total N, P, K, S and B contents of mustard stover	62

LIST OF TABLES (Contd.)

TABLE	TITLES OF TABLES	PAGES
4.10	Effect of sulphur on total N, P, K, S and B contents of mustard seed	64
4.11	Effect of boron on total N, P, K, S and B contents of mustard seed	67
4.12	Interaction effect of sulphur and boron on total N, P, K, S and B contents of mustard seed	69
4.13	Effect of sulphur on protein, oil contents and total uptakes of S and B by mustard	71
4.14	Effect of boron on protein, oil contents and total uptakes of S and B by mustard	72
4.15	Interaction effect of sulphur and boron on protein content, oil content and total uptake of S and B by mustard	75
4.16	Effect of sulphur on organic carbon, total N, available P, available K, available S, available B contents and p^H of the post harvest soil	77
4.17	Effect of boron on organic carbon, total N, available P, available K, available S, available B contents and p^H of the post harvest soil	80
4.18	Interaction effect of sulphur and boron on organic carbon, total N, available P, available K, available S, available B contents and p^H of the post harvest soil	83

LIST OF FIGURES

FIGURE	TITLE	PAGES
1	Map showing the experimental site under study	28
2	Layout of the experimental field	33

LIST OF APPENDICES

APPENDIX	TITLE	PAGES
Appendix Table 1	Records of meteorological information (monthly) during the period from October, 2007 to February, 2008	106
Appendix Table 2	Summary of analysis of variance of yield and yield attributes of mustard as influenced by different level of sulphur and boron	107
Appendix Table 3	Summary of analysis of variance of yield and yield attributes of mustard as influenced by different level of sulphur and boron	108
Appendix Figure 1	Field view of the experimental plot at 20 DAS	109
Appendix Figure 2	Field view of the experimental plot at 50 DAS	109
Appendix Figure 3	Field view of the experimental plot at 80 DAS	109

Chapter I

INTRODUCTION

CHAPTER 1

INTRODUCTION

Mustard *(Brassica* spp.) is one of the most important oilseed crops throughout the world after soyabean and groundnut (FAO, 2004). It has a remarkable demand as edible oil in Bangladesh. It occupies first position of the list in respect of area and production among the oilseed crops grown in this country (BBS, 2004). In the year of 2003-04 it covered 0.179 million hectares (ha) land and the production was 0.211 million metric tons (Mt), whereas the total oilseed production was 0.407 million Mt and total area covered by oilseed crops was 0.389 million ha. In the year of 2004-05 it covered 0.395 million ha land and the production was 0.379 million Mt. (BBS, 2005). Mustard seeds contain 40-45% oil and 20-25% protein (Mondal and Wahhab, 2001). Using local ghani average 33% oil may be extracted. Oil cake is a nutritious food item for cattle and fish. Oil cake is also used as a good organic fertilizer. Dry mustard plants may be used as fuel.

In Bangladesh, oilseed crops play a vital role in human nutrition. It is not only a rich source of energy (about 9 Kcal/g) but also rich in soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6g of oil for a diet with 2,700 Kcal.

Though the production of edible oil is being decreased, but the demand is increasing day by day with the increasing population. The present domestic edible oilseed production is 267 thousand tons which meets only one third of national demand (Anon. 2006).

From time immemorial, rapeseed oil plays an important role as a fat substitute in our daily diet. This is widely used as cooking ingredient. Moreover, mustard oil cake is not only used as a feed for cattle and fish but also used as good manure. Bangladesh has been in short of 65-70% of the demand of the edible oil. As a result, a huge amount of foreign currency is being drained out every year for importing oil and oil seeds from abroad.

Mustard plant belongs to the genus *Brassica* under the family Cruciferae. The *Brassica* has three species that produce edible oil, *B. napus, B. campestris* and *B. juncea.* Of these, *B. napus* and *B. campestris* have the greatest importance in the world's oilseed trade. In this subcontinent, *B. juncea* is also an important oilseed crop. Mustard varieties such as Tori-7, Sampad (both are *B. campestris*) and Doulat (*B. juncea*) are mainly grown in this country. Recently, MM-2-16-98. MM- 34-7, MM-38-6-98, MM-49-3-98, BINA sarisha-4 high yielding mutants/Varieties have been developed by the scientists of Bangladesh Institute of Nuclear Agriculture (BINA). Recently, in 2006 Sher-e-Bangla Agricultural University has developed a high yielding and improved mustard variety (SAU sarisha-1).

Mustard is a cold loving crop and grows during *Rabi* season (October-February) usually under rainfed and low input condition in this country. There is very little scope of expansion for mustard and other oilseed cultivation in the country due to competition from more profitable alternative crops. The cultivation of mustard has to compete with other food grain crops. With increasing growth rate of population, the demand of edible oil is increasing day by day. It is, therefore, highly expected that the production of edible oil should be increased considerably to fulfill the demand of the

country. But the production of mustard is hampered due to many reasons of which suitable varieties, imbalance use of fertilizers, negligible irrigation facilities and so on (Sheppard and Baten, 1980). Although mustard is the principal oil crop in Bangladesh its cultivation is much neglected.

Moreover, the average yield of rapeseed in Bangladesh is very low (0.812 t ha^{-1}) compared to that of other countries of the world. The average yield of rapeseed in Germany, France, UK, Poland, China and Japan is 3.70, 2.75, 2.85, 2.6, 1.8 and 1.6 t ha^{-1}, respectively (FAO, 2006). There is great possibility to increase its production by applying adequate fertilizers, selecting high yielding varieties and adopting proper management practices. One of the common constraints to higher yield is lack of balanced fertilization.

However, it is possible to increase the yield by adopting improved cultural practices. The use of high yielding varieties coupled with application of balanced fertilizers might be a good means to enhance mustard yield. The practice of intensive cropping with modern varieties cause a marked depletion of inherent nutrient reserves in soils of Bangladesh. Consequently, in addition to N, P and K deficiencies other nutrients such as S, Zn and B are also observed deficient in some soils (Islam, 1988; Ali *et al.*, 1988 and Jahiruddin *et al.*, 1992).

Sulphur is a macronutrient required for plant growth as in the same order as that of phosphorus (Zhao *et al.*, 1997).The need for S fertilizer depends on the balance between inputs and losses by leaching and other pathways of removal from agricultural systems. Mustard and oilseed rape are highly susceptible to S shortage,

and respond well to S fertilization (McGrath and Zhao, 1996; Zhao *et al.,* 1997). Further, the S nutrition of oil crops often has a strong influence on the quality of the produce, because of its essential role in the synthesis of amino acids (cystine, cysteine and metheonine), coenzymes (biotin, coenzyme A, liopic acid) and some secondary metabolites. Sulfur is responsible for characteristic taste and smell of mustard (Tisdale *et al.*, 1984). This emphasizes the need for a judicious use of S fertilizer.

Crops differ in their sensitivity to boron deficiency. *Brassica* crops in general have a high boron requirement (Mengel and Kirkby, 1987). Seed set failure is a major reason for lower yield of *rabi* crops and this problem can be attributed to boron deficiency, as reported in mustard (Rahman *et al.,* 1993; Islam *et al.,* 1997). Boron deficiency may cause sterility i,e. less pods and less seeds pod^{-1} attributing lower yield (Islam and Anwar, 1994). Deficiency of B causes restriction of water absorption and carbohydrate metabolism which ultimately affects seed and pod formation and thus reduces yield. Mehrotra *et al.* (1977) and Chatterjee *et al.* (1985) reported that seed yield of mustard increased by 15.5 - 68.5% due to boron application. In fertilizer schedule, an inclusion of B often decides the success and failure of the crops (Dwivedi *et al.,* 1990). It is reported that the ranges between deficiency and toxicity of B are quite narrow and that an application of B can be extremely toxic to plants at concentrations only slightly above the optimum rate (Gupta *et al.*, 1985). This emphasizes the need for a judicious use of B fertilizer.

Library

Objectives :

In Bangladesh, limited information is available on the effect of sulphur and boron on growth, yield, chemical composition and oil content of oil producing *Brassica spp.* With a view to generate information a field experiment containing the treatments of each of sulphur and boron was conducted with the following objectives:

- to compare the growth and yield performance of SAU sarisha -1 by using different doses of sulphur and boron.
- to know the interaction effect of sulphur and boron on nutrient content and uptake by plant and seeds of mustard.
- to identify the suitable doses of sulphur and boron for better yield of mustard.
- to study the effect of S and B on the chemical composition and oil content of mustard.
- to observe the interaction effect of S and B on the chemical composition and oil content of mustard.

Chapter II

REVIEW OF LITERATURE

CHAPTER –II

REVIEW OF LITERATURE

Rapeseed (*Brassica campestris* L.) is one of the most important oil seed crops in our country. It is necessary to improve the cultural practices of rapeseed to improve the yield of this crop under Bangladesh condition. Its growth and yield as well as quality are essentially influenced by proper fertilizer management especially by sulphur and boron. A very few workers conducted research using combined application of sulphur and boron. The available literature related to the present study is reviewed here.

2.1 EFFECT OF SULPHUR ON MUSTARD

Issa and Sharma (2006) conducted a field experiment during the winter season of 2003/04 and 2004/05 in New Delhi, India to study the effect of 4 levels (0, 15, 30 and 45 kg S ha^{-1}) of sulfur on yield attributes, yield and quality of Indian mustard. Yield attributes, seed and straw yields, oil content and oil yield, and sulfur content and uptake in both seed and straw increased significantly with increasing level of sulfur up to 45 kg S ha^{-1}. S at 15, 30 and 45 kg ha^{-1} increased seed yield over the control by 9, 16 and 23%; oil yield by 13, 22 and 33%; and sulfur uptake by 25, 48 and 65%, respectively.

Mehdi *et al.* (2006) observed that when Indian mustard plants were supplied with 20, 40, 60 and 80 kg sulfur ha^{-1} in a field experiment conducted in Uttar Pradesh, India during the *rabi* season of 2002-03 nitrogen and sulfur uptake increased with the growth of the crop but increased with increasing rates of sulfur during harvest. Seed oil content and yield, and protein yield increased with increasing rates of sulfur,

whereas sulfur and protein contents of the seeds increased with increasing rates of sulfur up to 60 kg ha^{-1} and decreased thereafter.

Naresh *et al.* (2006) conducted a field experiment during winter seasons *(rabi)* of 1999-2000 and 2000-01 in Agra, Uttar Pradesh, India to study the effect of graded levels of sulfur (0, 20, 40 and 60 kg ha^{-1}) on Indian mustard (*Brassica juncea cv. Rohini).* Indian mustard responded significantly to the application of S. The seed and stover yields increased linearly up to 40 kg S ha^{-1}. Application of 40 kg S ha^{-1} gave the highest seed yield (18.37 g ha^{-1}), which was 28.1% more in comparison with that of the control. The uptake of S significantly increased up to 40 kg S ha^{-1}. Oil content increased significantly with S addition. The added S were utilized maximum under application of the lowest levels of S.

Dongarkar *et al.* (2005) conducted a field experiment at Nagpur, Maharashtra, India during the *rabi* season of 2003-2004 to study the effect of three levels of sulfur (0, 20, 40 kg ha^{-1}) on growth, yield attributes and yield of mustard (*Brassica juncea).* The application of sulfur significantly influenced the growth and yield of mustard. Plant height, number of branches, dry matter production, number of siliquae, test weight, seed yield and stover yield ha^{-1} were significantly superior with the application of 40 kg S ha^{-1} over 20 kg S ha^{-1} and control.

Jahangir *et al.* (2005) conducted a study in Dhaka, Bangladesh during the winter season of 2002 to investigate the effects of S (0, 10, 20 and 30 kg ha^{-1}) on the growth, yield and nutrient content and oil quality of mustard [*Brassica juncea*] cv. Sonali. Seed yield and oil content increased with increasing rate of S. N, P and S contents of seed and straw varied with the treatments. The specific gravity, refractive index, moisture and acid value did not show variation with the treatments.

Rajbir (2005) conducted a field experiment in Punjab, India to study the performance of Indian mustard *(Brassica juncea)* genotypes RH 8814, RH-30, Bio 902 and PBR-91 in relation to sulfur levels (0, 20, 40 and 60 kg ha^{-1}). Application of sulfur in Indian mustard at 20 and 40 kg ha^{-1} significantly increased seed yield and its attributes, siliquae per plant, seeds per siliqua and test weight. Oil content and its production were also increased significantly with the application of sulfur levels over the control. The highest net returns were obtained with RH 8814 genotype treated with 40 kg S ha^{-1}.

Ramesh *et al.* (2005) conducted a field experiment in Haryana, India during the *rabi* seasons of 2002-03 and 2003-04 to study the effects of S application on the yield attributes, seed yield, S uptake, and seed oil content of Indian mustard (cv. RH-30). Four levels of S (0.0, 32.5, 65.0 and 97.5 kg ha^{-1}) were applied through gypsum. S application significantly increased the number of primary branches, number of siliquae per plant, length of siliqua, and 1000-seed weight. Optimum seed yield (14.9 quintal ha^{-1}) was obtained with the application of 65.0 kg S ha^{-1}. S application also increased the stover and total dry matter yields. The application of S up to 97.5 kg ha^{-1} increased the S uptake by seeds. The oil content of seeds increased up to 32.5 kg S ha^{-1}. The mean value of recovery on added S varied from 13.8 to 21.6%. S use efficiency was higher with the lower rate of S. [1 quintal=100 kg].

Birbal *et al.* (2004) conducted two field experiments during the 1996/97 and 1997/98 winter seasons in Jabalpur, Madhya Pradesh, India to determine the effects of S fertilizer rates (0, 20, 40 and 60 kg ha^{-1}) on the yield and yield components of Indian mustard cv. Pusa Bold. S at 60 kg S ha^{-1} gave the maximum plant height, number of primary branches, leaf area index at 60 days after sowing, siliquae $plant^{-1}$, seeds

siliqua^{-1}, 1000-seed weight, grain yield and stalk yield. The highest net monetary returns and benefit : cost ratio were obtained with 40 kg S ha^{-1}.

Brajendra and Shukla (2004) observed that when three levels of S (0, 30 and 60 mg/kg) were supplied to mustard cv. Varuna, grown in 5-kg pots containing 4 kg surface soil samples (Alfisols and Ultisols) collected in bulk from 20 different sites from the plateau region of Jharkhand (India), comprising the districts of Dhanbad, Giridih, Hazaribagh and Ranchi. The dry matter yield, S content and its uptake increased with increasing levels of S application.

Hidyatullah *et al.* (2004) conducted a field experiment during *rabi* 2000 in Uttar Pradesh, India to study the effect of 4 levels of sulfur (0, 7, 14 and 21 kg ha^{-1}) on the growth, yield and biochemical parameters of Indian mustard *(Brassica juncea).* Application of sulfur produced a significant and consistent increase in number of siliqua per plant, seed yield and oil content of mustard with increasing levels of sulfur up to 21 kg ha^{-1}, whereas 1000-seed weight and number of seeds per siliqua showed significant improvement with sulfur application only up to 14 kg ha^{-1}. Plant height and seed protein content did not respond to the sulfur application.

Singh and Dhiman (2004) reported that leaf area index, number of primary branches per plant, dry weight, number of siliquae per plant, number of seed siliquae per plant, test weight, seed yield, stover yield, harvest index, protein and oil content, and oil yield of mustard increased with increasing rates of sulfur.

Singh *et al.* (2004) conducted an experiment in Bikaner, Rajasthan, India during winter season of 1999-2000 to study the response of Indian mustard cv. T-59 to sulfur rates. Treatments comprised: four sulfur levels (0, 20, 40 and 60 kg ha^{-1}).Sulfur

fertilizer application at 20 kg ha^{-1} increased oil content in mustard over the control. Oil yield and chlorophyll content were enhanced up to 40 kg S ha^{-1}.

Abdin *et al.* (2003) reported that the yield and quality of rapeseed-mustard can be optimized with the split application of 40 kg S ha^{-1} during the appropriate phenological stages of crop growth and development.

Amar and Meena (2003) conducted a field experiment during the 1996/97 and 1997/98 winter seasons in Bharatpur, Rajasthan, India to determine the effect of S fertilizers on the oil and protein yield of Indian mustard cv. Varuna. The treatments comprised 0, 20, 40, 60 and 80 kg S ha^{-1}. Pooled analysis of data showed that 80 kg S ha^{-1} gave the highest oil content 39.48%. S at 80 kg S/ha gave the highest oil yield of 721.5 kg ha^{-1}. S at 80 and 60 kg/ha also gave the highest protein content (19.99%) and protein yield (369.0 kg/ha), respectively. The most profitable rates of S during 1996/97 and 1997/98 were 79.83 and 68.65 kg ha^{-1}, respectively.

Bharati and Prasad (2003) observed that seed yield, 1000-seed weight and net returns did not significantly vary with the S rate. The application of 45 kg S ha^{-1} resulted in the highest oil content (41.84%) and oil yield (0.63 t ha^{-1}). The highest dry matter production and S uptake were recorded for 15 and 30 kg S ha^{-1}.

Jat and Khangarot (2003) conducted a field experiment during *rabi* season of 1999-2000 on a loamy sand soil of Jobner, Rajasthan, India to study the response of Indian mustard cultivars PCR-7, RH-8812, Bio-902 and CS-52 to 4 levels of S (0, 30, 60 and 90 kg ha^{-1}). Application of 90 kg S ha^{-1} significantly enhanced all growth parameters, yield attributes and seed and stover yields (19.38 and 44.26 q ha^{-1}, respectively) over their preceding levels.

Misra (2003) conducted field experiments on mustard crop (cv. Varuna) with four levels of sulfur (0, 20, 40 and 60 kg S ha^{-1}) on Udic Haplustepts of Kanpur, Uttar Pradesh, India during *rabi* seasons of 1998-99 and 1999-2000. Results showed that mustard crop responded significantly to the application of S ha^{-1}. The seed and stover yields increased in the linear order up to 40 kg S. The highest seed yield (2,035 kg ha^{-1}) at 40 kg S ha^{-1} was 27.59% higher in comparison to the yield at control. The uptake of N, K and S at maturity was significantly affected with treatments. The P uptake significantly increased up to 40 kg S ha^{-1} and thereafter, decreased significantly. Percent utilization of added S was maximum when lowest levels of S were applied. Oil, protein and total S-amino acid contents increased significantly with the application of S. Sulfur addition also significantly influenced the fatty acids composition; oleic and linoleic acid contents increased and erucic acid decreased showing improved quality of mustard oil.

Chauhan *et al.* (2002) reported that increasing S levels significantly improved the growth, yield attributes (plant height, primary branches per plant, siliqua length, siliquae per plant, seeds per siliqua and 1000-seed weight), seed yield and oil content of Indian mustard. The highest seed yield, oil content and net returns were obtained with 60 kg S ha^{-1}.

Om and Singh (2002) conducted an experiment to know the effects of sulfur rate (0, 20, 40, and 60 kg ha^{-1}) on Indian mustard in Agra, Uttar pradesh, India during the winter seasons of 1996/97 and 1997/98. Sulfur as gypsum was incorporated into the soil. Seed yield, protein and oil contents, and oil yield increased with the increase in sulfur rate up to 40 kg ha^{-1} only.

Sandeep *et al.* (2002) revealed that the application of 30 kg S/ha gave the highest number of siliquae per plant (360.35), weight of siliquae per plant (28.67 g), number of seeds per siliqua (13.72), seed yield per plant (337.17 g), 1000-grain weight (4.93 g) and seed yield per ha (15.14 quintal). The highest oil contents were obtained with S at 20 (37.89%) and 30 kg/ha (37.95%).

Singh *et al.* (2002) conducted a field experiment during the winter seasons of 1996-98 in Agra, Uttar Pradesh, India to study the performance of Indian mustard in relation to S application (0, 20, 40, and 60 kg ha^{-1}). S application at 20 and 40 kg ha^{-1} improved the seed yield significantly, indicating 46.7 and 63.4% increase over the control. Oil content and its production was also increased significantly with the application of S over the control. The highest net returns (Rs 14, 725 ha^{-1}) were obtained with Pusa Bahar supplied with 40 kg S ha^{-1}.

Sudhakar *et al.* (2002) found that S significantly improved plant height, number of primary and secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, test weight, seed yield and stover yield. The increase in these parameters was observed up to 60 kg S ha^{-1}.

Suresh *et al.* (2002) reported that S at 60 kg ha^{-1} gave the highest seed (1.809 t ha^{-1}) and oil (0.756 t ha^{-1}) yields, siliqua number per plant (475.85), siliqua length (6.17 cm), seed number per siliqua (13.42), 1000-seed weight (4.43 g), and uptake of N (108.58 kg ha^{-1}), P (16.77 kg ha^{-1}), K (85.06 kg ha^{-1}), S (33.77 kg ha^{-1}), and Fe (1.87 kg ha^{-1}). The highest benefit : cost ratio (2.034) was obtained with gypsum at 60 kg S ha^{-1}.

Varma *et al.* (2002) found that sulfur significantly increased seed and stover yields, oil content, and yield attributing characters of Indian mustard such as siliqua plant^{-1}, seeds siliqua^{-1}, length of siliqua and test weight only up to 30 kg ha^{-1}.

Krauze and Bowszys (2001) showed that the effect of sulphur on spring oilseed rape showed that as for soil of low sulphur content (14.3 mg S-SO_4·kg^{-1} of soil) fertilization with a dose of 12 kg S ha^{-1} increased the seed yield from 8.14 to 14.7% as compared with the yield from non-fertilized plants.

Trzciński (2001) reported that sulphur fertilization in the experiment increased the mean seed yield from 6.61 to 33.4% as compared with the control. The highest mean yield was obtained due to foliar fertilization of oilseed rape with elemental S at the dose of 60 kg ha^{-1}. The sulphur form applied not only increased yield but also improved the phytosanitary status, inhibiting the development of fungal pathogens of *Alternaria* genus, especially *Alternaria brassicae* and *Alternaria brassicicola* species.

Haneklaus *et al.* (1999) reported that the highest yield was recorded for oilseed rape fertilized with 40 kg S ha^{-1} cultivated on plots of low sulphur content, and the yield obtained was 65% higher than that from control objects (poor in sulphur). A weak reaction of oilseed rape to fertilization with sulphur which coincided with a good sulphur supply.

Patel and Shelke (1999) revealed that vegetative growth characters of mustard increased significantly by increasing levels of phosphorous and sulphur up to 120 kg P_2O_5 and 60 kg S ha^{-1}, respectively.

Tomar *et al.* (1997) found in an experiment which consist of different levels of nitrogen (60, 80 and 120 kg ha^{-1}), phosphorous (0, 40 and 80 P_2O_5) and sulphur (0, 40 and 80 kg S ha^{-1}) and observed that yield attributes (siliquae $plant^{-1}$) increased significantly with the increasing levels of N, P and S up to 120, 80 and 80 kg ha^{-1}, respectively.

Bilsborrow *et al.* (1995) showed a varied effect of sulphur fertilization on oilseed rape yield depending on the sulphur content in soil and in the air. The highest yield was recorded for oilseed rape fertilized with 40 kg S ha^{-1} cultivated on plots of a low sulphur content, and the yield obtained was 65% higher than that from control objects (poor in sulphur).

Schnug and Haneklaus (1995) showed that the sulphur uptake by oilseed rape took place especially in spring from the beginning of vegetation period to the end of flowering at the amount of 15-20 kg S ha^{-1} of seeds produced. According to these authors, fertilizing plants with this macro element enhances the yield, content of fat and sulphur amino acids.

Ali *et al.* (1994) observed that yield attributes, seed and stover yields, harvest index progressively increased with the increasing level of sulphur.

Amin *et al.* (1994) observed the seed yield and stover yield of Tori-7 and TS 72 increased significantly by the application of S up to 20 kg ha^{-1} while the seed yield of SS-75 increased up to 40 kg ha^{-1}.

Singh and Kumar (1994) found that sulphur @ 40 kg ha^{-1} significantly increased the siliqua length of Indian mustard compared with 0 and 20 kg S ha^{-1}.

Rajput *et al.* (1993) revealed that application of 10 to 30 kg sulphur ha^{-1} increased *Brassica juncea* seed yield compared with control. The highest yield was given by 20 kg S ha^{-1}, with no significant difference between sources (gypsum, ammonium sulphate and single super phosphate).

Sarkar *et al.* (1993) worked with four high yielding varieties of mustard viz. BAU-M248 (Sampad, M-257 and SS-75 (Sonali sarisha). They applied five levels of sulphur viz. 0, 10, 20, 30 and 40 kg S ha^{-1} to the crops and found jat BAU- M248 (Sampad) gave the maximum yiekld @ 40 kg S ha^{-1} and the variety sampad followed Sambol in respect of seed yield at the same level of S, both the varieties M-257 and SS-75 gave the maximum seed yield @ 40 kg S ha^{-1}.

Wielebski and Wójtowicz (1993) observed in winter oilseed rape that the seed yield of 3.5 t ha^{-1} requires 88 kg of sulphur.

Khanpara *et al.* (1992) observed that plant height, primary and secondary branches $plant^{-1}$ increased up to 100 kg S ha^{-1} and subsequently and significantly increased seed yield. The modes of S application did not attain the level of significance for all the growth characters and seed yield of mustard.

Sharma *et al.* (1992) reported that the highest yield (2.19 t ha^{-1}) of *Brassica juncea* obtained from 60 kg S ha^{-1} when they were given 0, 15, 30, 45, and 60 kg S ha^{-1}. The lowest yield (1.20 t ha^{-1}) was obtained from control.

Chaudhury *et al.* (1991) conducted a field experiment with Varuna mustard during 1988-89. The treatments consisted of 4 levels of S (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters except 1000-seed weight were influenced significantly

up to the highest level of N (80 kg N ha^{-1}). Sulphur increased seeds $siliqua^{-1}$, seed weight $plant^{-1}$ and ultimately seed yield ha^{-1}. Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg S ha^{-1}.

Dubey and Khan (1991) reported that S up to 30 kg ha^{-1} significantly increased the seed yield of mustard.

Evans *et al.* (1991) observed that the highest yield was recorded for oilseed rape fertilized with 40 kg S ha^{-1} cultivated on plots of low sulphur content, and the yield and seed weight obtained was 65% higher than that from control (poor in sulphur). A weak reaction of oilseed rape to fertilization with sulphur which coincided with a good sulphur supply.

Mohan and Sharma (1991) observed that S @ 75 kg ha^{-1} significantly increased primary and secondary branches $plant^{-1}$. Sulphur @ 50 kg ha^{-1} increased the plant height significantly.

Saran and Giri (1990) reported from a couple of experiments that application S influenced the plant growth and yield attributes. They found that height and primary branches/plant significantly increased with 60 kg ha^{-1} of S. Number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000-seed weight were also increased significantly with 60 kg ha^{-1} of S and seed weight/plant increased with 30 kg ha^{-1} of sulphur.

Koti *et al.* (1989) conducted field trials at Dharwad in 1989. Mustard was given @ 22 kg S ha^{-1} at sowing time. Average siliqua yield ranged from 1.83 t ha^{-1} (without sulphur) to 2.31 t ha^{-1} (with 18 kg S ha^{-1}). Siliqua yield was significantly affected by the levels of sulphur.

Ali *et al.* (1988) conducted experiments at Non Calcareous Dark Grey Floodplain and Grey Floodplain Soils with mustard (BINA sarisha-1) and found that at 40 kg S ha^{-1} seed yield of mustard was 300% more than that was obtained in S control plots. Increase in yield due to S rates of 20 kg and 60 kg ha^{-1} were 226% and 317%, respectively.

Singh *et al.* (1987) observed that application of 30 kg S ha^{-1} to mustard gave yields of 1.16 tha^{-1} compared with 1.00 t ha^{-1} without S. Yield was not further increased with 60 kg ha^{-1}.Sulphur increased oil and protein contents, N and S uptake.

BARI (1985) reported that the number of filled siliqua $plant^{-1}$ of mustard and plant height increased significantly due to the application of S.

Chatterjee *et al.* (1985) observed that the number of seeds $siliqua^{-1}$ and yield were increased due to the application of S at 20 kg ha^{-1} through gypsum in conjunction with borax 10 kg ha^{-1}. This was due to the increase in the number of siliqua $plant^{-1}$.

Singh (1984) studied the effect of S fertilization on different growth stages and reported that S fertilization increased the number of primary branches $plant^{-1}$.

Singh and Singh (1984) reported that the application of 90 ppm S increased the number of mature seed $siliqua^{-1}$.

Shukla *et al.* (1983) concluded that the application of S and Zn significantly increased the concentration of and uptake of these elements. Seed yield was significantly increased by the application either alone or in combination. Singh and Bairathi (1980) also reported that the S @ 75-80 kg ha^{-1} increased the seed yield of *Brassica juncea.*

BARI (1982) reported that application of S was favorable for the production of more seeds siliqua^{-1} in comparison to plants fertilized without sulphur.

Singh and Bairathi (1980) reported that the seed yields, N,P and S uptake and oil content and protein contents in of *Brassica juncea* were increased with 75-150 kg S and/or 40 kg N ha^{-1}.

Rahman *et al.* (1978) reported that the application of sulphur was favorable for the production of more seeds siliqua^{-1} and mature seed siliqua^{-1}.

From the above information it may be inferred that the optimum level of sulphur has a positive effect on seed yield and growth parameters.

Library

2.2 EFFECT OF BORON ON MUSTARD

Halder *et al.* (2007a) conducted a field experiment in Jessore, Bangladesh during the 2000/01 and 2001/02 cropping seasons to evaluate the effect of boron on the yield of mustard and to screen out the suitable cultivar(s) tested against different B levels for maximizing yield of mustard. The treatments comprised 4 mustard cultivars (BARI Sharisha-6, 7, 8 and 9); and 4 B levels (0, 1.0, 1.5 and 2.0 kg ha^{-1}) along with a blanket dose of N_{120} P_{35} K_{65} S_{20} Zn_5 kg and 5 t cow dung ha^{-1}. Results revealed that BARI Sharisha-6 integrated with 1.5 kg B ha^{-1} was superior to all other treatment combinations. On the other hand, 1.5 kg B/ha individually increased the highest seed yield by 58.83%, over the control. However, from regression analysis, a positive but quadratic relationship was observed between seed yield and B levels.

Halder *et al.* (2007b) conducted field studies in non-calcareous dark grey floodplain soils (AEZ-1) in Rajbari, Dinajpur, Bangladesh during the 2000/01 and 2001/ 02 *rabi*

seasons, to determine the optimum boron fertilizer application rate and evaluate a suitable cultivar for maximizing the yield of mustard. Four cultivars, i.e. BARI Sarisha-6, BARI Sarisha-7, BARI Sarisha-8 and BARI Sarisha 9, integrated with 4 B fertilizer levels (0, 1.0, 1.5 and 2.0 kg B/ha) along with a blanket rate of 120 kg N, 35 kg P, 65 kg K, 20 kg S and 5 kg Zn ha^{-1} and cow dung at 5 t/ha. The interaction effect of cultivar and B had a significant response on the yield components of mustard. The highest seed yield (2.23 t ha^{-1}) was recorded in BARI Sarisha-6 with 2 kg B/ha in the second year (2001/ 02), while in the first year (2000 / 01), the recorded yield was 1.51 t ha^{-1}, which was statistically significant over the B control. However, the highest mean seed yield (1.87 t ha^{-1}) was obtained from the same treatment combination by 35.5% yield increase in both years of study. Though the individual effects of B and cultivar were more pronounced than their interaction, BARI Sharisha-6 and 2 kg B ha^{-1} separately augmented highest seed yields of mustard (1.91 and 1.98 t ha^{-1}) for both years of the study when a blanket dose of other fertilizers were ensured. In regression analysis, a linear relationship between seed yield and the B levels was observed in the mean seed yield of the 2 consecutive years of study, which meant that beyond the level, the seed yield might be declined due to the toxic effect of excess B rates.

Sen and Farid (2005) reported that application of boron @ 1.5 kg ha^{-1} produced 37% higher yield over control.

Malewar *et al.* (2001) conducted a field experiment on a Typic Haplustert in Maharashtra, India to investigate the effects of four levels of zinc sulfate (0, 10, 20 and 30 kg ha^{-1}) and three levels of borax (0, 5 and 10 kg/ha) on yield, nutrient uptake and seed quality of mustard (*Brassica juncea* cv. Pusa Bold). Stover and seed yield significantly increased with each levels of either zinc or boron, which was attributed

to the positive interaction of the two. Highest total mustard uptake of Zn and B was at 30 kg $ZnSO_4$ and 10 kg borax/ha, respectively. Zn and B interaction was also reflected in terms of improved seed quality of mustard. Oil and protein content was significantly increased with 30 kg $ZnSO_4$ x 10 kg borax ha^{-1} treatment.

Sinha *et al.* (2000) stated that mustard (*Brassica campestris*) cv. T9 was grown in refined sand at three levels of boron : deficient (0.0033 ppm), normal (0.33 ppm), and excess (3.3 ppm), each at three levels of zinc : low (0.00065 ppm), adequate (0.065 ppm), and high (6.5 ppm). The B deficiency effects were accentuated by low zinc, viz. the decreased biomass, B and Zn concentrations in leaves and seeds and the activity of carbonic anhydrase [carbonate dehydratase] and accumulation of reducing sugars and stimulated activities of peroxidase, ribonuclease, and acid phosphatase in B deficient leaves were aggravated further. Synergism was also observed between the two nutrients when both B and Zn were in excess together, as excess B accelerated the effects of high Zn by lowering further the reduced biomass, economic yield, and carbonic anhydrase activity and raised further the increased concentration of B and Zn in leaves and seeds, reducing sugars and activity of peroxidase obtained in excess Zn. High Zn levels lowered the high content of non-reducing sugars given by B deficiency.

Gupta *et al.* (1996) reported that mustard [*Brassica juncea*] cv. GSL-1, Pusa Bold and RS-1359 grown in the *rabi* [winter] seasons of 1992/93 and 1993/94 were given recommended NPK fertilizers plus 10 or 20 kg Zn ha^{-1}, foliar application of 0.5% Zn, 25 or 50 kg S/ha, or 10 or 20 kg B ha^{-1}. Seed yield was highest in cv. GSL-1, and was increased more by S and B than by Zn.

Islam and Sarker (1993) reported that the application of boron increased significantly the number of siliquae plant^{-1}, no. of seeds siliqua^{-1} and seed yield of mustard (cv. ss-75) at Rangpur Agricultural Research Station. From another study it was reported that application of boron on mustard (cv. ss-75) significantly increased the seed yield in farmer's field at Jamalpur.

Pradhan and Sarkar (1993) conducted a field trials on a sandy loam soil in West Bengal in *rabi* [winter] of 1989/90 and found that application of 20 kg S and 1 kg B ha^{-1} to rape-seed mustard [*Brassica juncea*] significantly increased plant height, leaf area index at flowering and crop growth rate, oil content and seed yield.

Sakal *et al.* (1991) conducted a field trials in 1987-88 with 6 cultivars each of sesame and mustard *[Brassica juncea]* grown with applied NPK + Zn on a B-deficient soil and found that av. sesame seed yields increased from 502 to 569 kg ha^{-1} and mustard seed yields increased from 1.14 to 1.35 t ha^{-1} when 1.5 kg B ha^{-1} was applied; yields were decreased to 518 kg and 1.30 t, respectively, with 2.5 kg B ha^{-1}. Sesame cv. OMT-11-6-3 and RT-54 and mustard cv. Pusa Bold were more tolerant of B deficiency than other cultivars, as they removed more B from the soil given no B. They also showed a lower yield response to applied B than more susceptible cultivars. There was a positive correlation between seed B content and uptake. Yield was positively correlated with seed B uptake.

Sinha *et al.* (1991) reported that application of boron significantly increased the yield of mustard and 1.5 kg B ha^{-1} appeared to be the optimum B level for mustard.The straw yield of mustard crop increased significantly by boron application.

Library

Banuels *et al.* (1990) reported that the application of P, S, Zn, and B raised seed yield of mustard significantly.

Marschner (1990) reported that the deficiency symptoms of some boron sensitive crops like legumes, *Brassica*, beets, celery, grapes and fruit trees showed chlorosis and browning of young leaves, killed growing points, distorted blossom development, lesions in pith and roots, and plants, burning of the tips of the leaves and restricted root growth are the boron toxicity symptoms in most crops.

Sharma and Ramchandra (1990) reported that boron deficiency in mustard (*B. campestris*) decreased dry matter yield. Boron deficient plant had low water potential, stomatal pore opening and transpiration, decreased chlorophyll concentration, hill reaction activity, inter-cellular concentration and photosynthesis but there was an increase in accumulation of soluble nitrogen, protein, sugar and starch.

Yang *et al.* (1989) reported that combined application of N, K and B increased seed yield in rapeseed. Application of B along with N and K promoted CO_2 assimilation, nitrate reductase activity in leaves and dry matter accumulation. Seed glucosinolate and erucic acid content varies among cultivars and generally decreases with increasing K and B, while seed oil content increases.

Chatterjee *et al.* (1985) reported that the application of sulphur at the rate of 20 kg ha^{-1} through gypsum in conjugation with borax (10 kg ha^{-1}) caused 42% increase in yield of mustard (*B. juncea*).

Thomas (1985) reported that the highest yields were achieved on medium to heavy soil with 40 kg N and P, 80 kg K, 1 kg B and 30 kg S ha^{-1} applied before sowing, plus

180 kg to 220 kg N ha^{-1} applied as top dressing in two installments in late February to early March.

Saini *et al.* (1985) observed that seed yield *of B. juncea* were increased by increasing N rates from 0 to 120 kg and 1 kg B ha^{-1}. The response to S, Zn and B increased with increase in N rates. Oil content decreased slightly with increasing N rates and increased slightly with S, Zn and B.

Dixit and Shukla (1984) reported that application of boron significantly increased the yield of mustard and 1.5 kg B ha^{-1} appeared to be the optimum B level for mustard

Dutta *et al.* (1984) stated that application of B (1 kg /ha) increased leaf area ratio (LAR), leaf area index (LAI), crop growth rate (CGR), no. of brunches $plant^{-1}$, no. of siliquae $plant^{-1}$, weight of seed $siliqua^{-1}$ and a decrease in chlorophyll content and net assimilation rate (NAR), but the relative growth rate (RGR), total dry matter and seed yield and some of other growth attributes were unaffected.

Dugger (1983) and Lewis, (1980) reported that the function of boron is primarily extra cellular and related to lignifications and xylem differentiation, membrane stabilization and altered enzyme reactions. Plants absorb B principally in the form of H_3BO_3 and to a smaller extent as $B_4O_7^{2-}$, $H_2BO_3^-$ and HBO_3^{2-}. The element plays a vital role in the physiological processes of plants such as cell nutrition, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinins synthesis, auxins and phenol metabolism.

Dutta and Uddin (1983) stated that application of B (1 kg ha^{-1}) increased leaf area ratio (LAR), leaf area index (LAI), crop growth rate (CGR), no. of brunches $plant^{-1}$,

no. of siliquae plant^{-1}, weight of seed siliqua^{-1} and a decrease in chlorophyll content and net assimilation rate (NAR), but the relative growth rate (RGR), total dry matter and seed yield and some of other growth attributes were unaffected.

Yadav and Manchanda (1982) observed that increasing rate of B application from 0 to 6 ppm had no effect on dry matter and seed yield of mustard but tissue B content increased.

Agarwala *et al.* (1981) found that direct effects of boron are reflected by the close relationship between boron supply and pollen producing capacity of the anthers as well as the viability of the pollen grains.

Juel (1980) reported from 17 trials that the application of boron at the rate of 2 kg ha^{-1} resulted in increased seed yield of mustard and oil content of seed.

Gupta (1979) stated that some plant species have a low B requirement and may also be sensitive to elevated B level even only slightly above those needed for normal growth. Therefore, toxic effects of B are likely to arise due to excessive use of B fertilizers.

Chakravarty *et al.* (1979) stated that boron concentration in all crops increased significantly with increasing level of applied boron.

Erikson (1979) reported that boron has both direct and indirect effects on fertilization. Indirect effects are related to the increase in amount and change in sugar composition of the nectare, whereby the flowers of species that rely on pollinating insects become more attractive to insects.

Gupta (1979) reported that boron is a micronutrient requiring for plant growth relatively to a smaller amount. The total B content of soils lies between 20 and 200 ppm with the available (hot water soluble) B fraction ranging from 0.4 to 0.5 ppm . Gerath *et al*. (1975) reported an increase in yield of winter rape through application of boron fertilizer and recommended an application of 1 to 2 kg B ha^{-1} for increased yield.

Jakson and Chapman (1975) observed that boron stimulates germination, particularly pollen tube growth. Boron is also essential for sugar translocation, thus affecting carbon and nitrogen metabolism of plants.

From the above information it may be concluded that the optimum level of boron has a positive effect on seed yield but the growth and yield is depressed due to deficient or toxic level of boron.

07/10/09
A. 30
37623

3.3 INTERACTION EFFECT OF SULPHUR AND BORON ON MUSTARD

Pradhan and Sarker (1993) reported that application of 20 kg S and 1 kg B ha^{-1} to rape-seed mustard [*Brassica juncea*] significantly increased plant height, leaf area index at flowering and crop growth rate, oil content and seed yield.

Thomas (1985) reported that the highest yields were achieved on medium to heavy soil with 1 kg B and 30 kg S ha^{-1} applied before sowing, plus P, K and N applied as basal dose and top dressing in two instalments in late February to early March.

Chapter III

MATERIALS AND METHODS

CHAPTER - III
MATERIALS AND METHODS

This chapter includes a brief description of the experimental soil, mustard variety, land preparation, experimental design, treatments, cultural operations, collection of soil and plant samples etc. and analytical methods followed in the experiment. The experiment was conducted at Sher-e-Bangla Agricultural University Farm, Sher-e-Bangla Nagar, Dhaka during November 2007 to February 2008 to find out the effect of sulphur and boron on the growth, yield, chemical composition and oil content of mustard (variety SAU sarisha -1)

3.1 Experimental site and soil

The experimental site was located at $23^0 77'$ N latitude and $90^0 3'$ E longitude with an elevation of 1.0 meter from sea level (Fig. 1). The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ - 28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm before initiation of the experiment and analyzed in the laboratory. The morphological characteristics of the experimental field and initial physical and chemical properties of soil are shown in Table 3.1 and 3.2.

Figure 1. Map showing the experimental site under study

Table 3. 1 Morphological characteristics of experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ No. and name	AEZ-28, Modhupur Tract
General soil type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land type	High land

Table 3. 2 Initial physical and chemical properties of the experimental soil

Soil properties	Value
A. Physical properties	
1. Particle size analysis of soil.	
% Sand	29.04
% Silt	41.80
% Clay	29.16
2. Soil texture	Clay loam
B. Chemical properties	
1. Soil pH	6.16
2. Organic carbon (%)	0.68
3. Organic matter (%)	1.17
4. Total N (%)	0.08
5. C : N ratio	9.75 : 1
6. Available P (ppm)	13.42
7. Available K (ppm)	45
8. Available S (ppm)	23.74
9. Available B (ppm)	0.38

3.2 Climate

The experimental area has sub tropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm. The experiment was carried out during *rabi* season of 2007-08. Air temperature during the cropping period ranged from 13.32^0C to 34.12^0 C. The relative humidity varied from 62.55% to 96.70% and monthly rainfall varied from 0.64 mm to12.12 mm from the beginning of the experiment to harvesting. The monthly maximum and minimum temperature, humidity and rainfall of the site during the experimental period are given in appendix Table 1.

3.3 Seeds and variety

SAU sarisha-1, a high yielding and short duration variety of mustard (*Brassica campestris*) developed by Sher-e-Bangla Agricultural University (SAU), Dhaka was used in the experiment. The seeds were collected from Genetics and Plant Breeding Depatrment of Sher-e-Bangla Agricultural University, Dhaka.

3.4 Design and layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each fertilizer treatment combinations. Fertilizer treatments consisted of 4 levels of S (0, 15, 25 and 35 kg S ha^{-1} designated as S_0, S_1, S_2 and S_3, respectively) and 4 levels of B (0, 1, 2 and 4 kg B ha^{-1} designated as B_0, B_1, B_2 and B_3, respectively). There were 16 treatment combinations. The treatment combinations were as follows:

Four rates each of S and B were used. The rates of S and B and their treatment combinations are shown below:

A. Rates of sulphur (4):

1. S_0 = No sulfur
2. S_1 = 15 kg S ha^{-1}
3. S_2 = 25 kg S ha^{-1}
4. S_3 = 35 kg S ha^{-1}

B. Rates of boron (4):

1. B_0 = No boron
2. B_1 = 1kg B ha^{-1}
3. B_2 = 2 kg B ha^{-1}
4. B_3 = 4 kg B ha^{-1}

Treatment Combinations

1. S_0B_0 = Control (without S and B)
2. S_1B_0 = 15 kg S ha^{-1} + 0 kg B ha^{-1}
3. S_2B_0 = 25 kg S ha^{-1} + 0 kg B ha^{-1}
4. S_3B_0 = 35 kg S ha^{-1} + 0 kg B ha^{-1}
5. S_0B_1 = 0 kg S ha^{-1} + 1 kg B ha^{-1}
6. S_1B_1 = 15 kg S ha^{-1} + 1 kg B ha^{-1}
7. S_2B_1 = 25 kg S ha^{-1} + 1 kg B ha^{-1}
8. S_3B_1 = 35 kg S ha^{-1} + 1 kg B ha^{-1}
9. S_0B_2 = 0 kg S ha^{-1} + 2 kg B ha^{-1}
10. S_1B_2 = 15 kg S ha^{-1} + 2 kg B ha^{-1}
11. S_2B_2 = 25 kg S ha^{-1} + 2 kg B ha^{-1}
12. S_3B_2 = 35 kg S ha^{-1} + 2 kg B ha^{-1}
13. S_0B_3 = 0 kg S ha^{-1} + 4 kg B ha^{-1}
14. S_1B_3 = 15 kg S ha^{-1} + 4 kg B ha^{-1}
15. S_2B_3 = 25 kg S ha^{-1} + 4 kg B ha^{-1}
16. S_3B_3 = 35 kg S ha^{-1} + 4 kg B ha^{-1}

Fertilizer treatments were randomly distributed in each block. Each block consisted of 16 plots and individual plot was 2m × 2m i.e., 4 sq. m in size. The row to row distance was 30 cm. Seeds were sown in continous line. The adjacent block and neighboring plots were separated by 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Fig. 2.

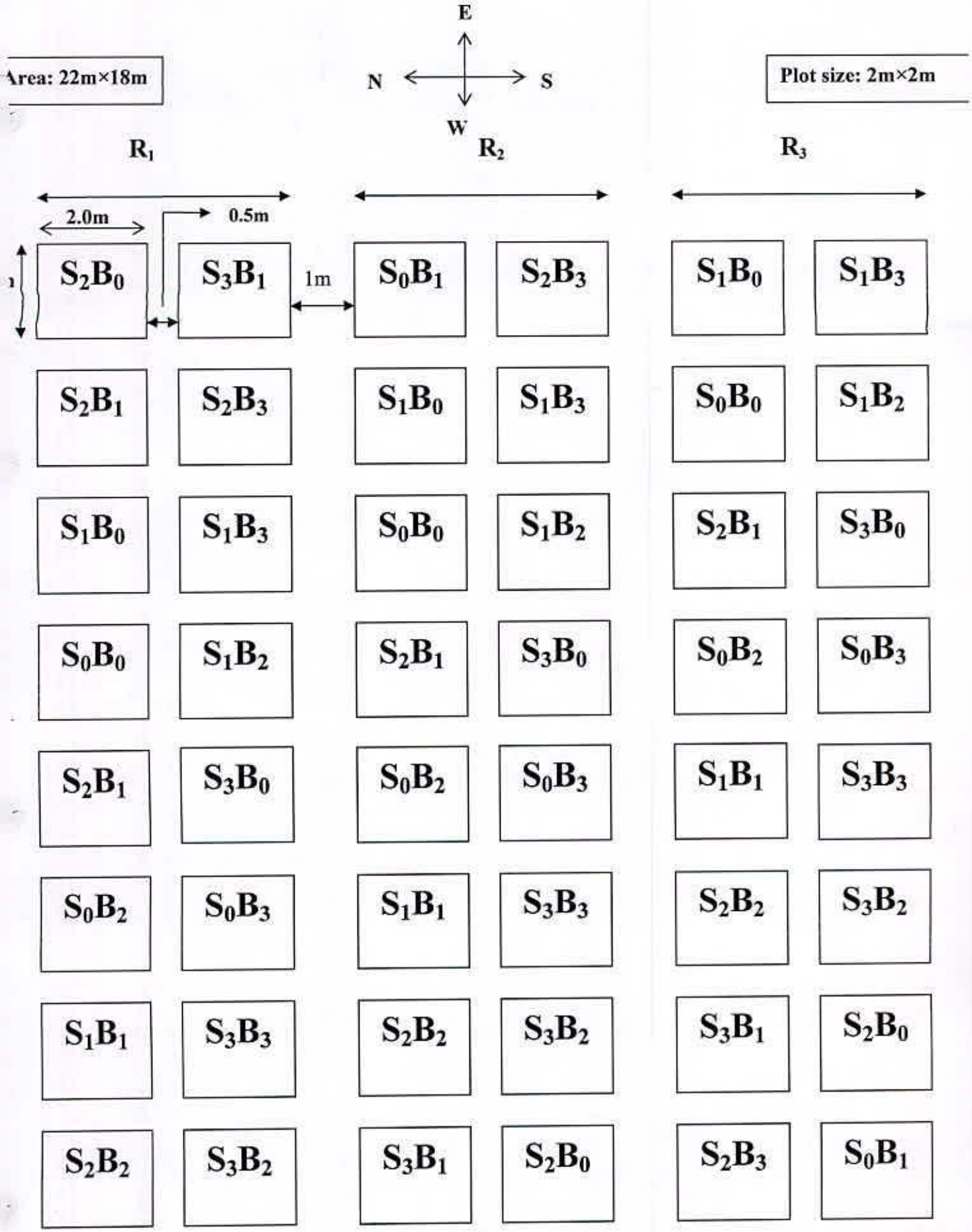

Figure 2. Layout of the experiment in RCBD

3.5 Collection and processing of composite soil sample

Soil samples from the experimental field were collected before land preparation to a depth of 0-15 cm from the surface on the basis of composite sampling method. The collected soil was air-dried, ground and passed through a 2-mm sieve and stored in a clean, dried plastic container for physical and chemical analysis.

3.6 Land preparation

The land was first ploughed with a tractor drawn disc plough on 3 November, 2007. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The land preparation was completed on 10 November, 2007. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.7 Application of fertilizers

Recommended doses of N, P, K and Zn (110 kg N from urea, 35 kg P from TSP, 40 kg K from MP and 4 kg Zn ha^{-1} from ZnO, respectively) were applied.

The whole amounts of TSP, MP, Zinc oxide and half of the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 20 - 22 days of germination (before flowering). The required amounts of S (from gypsum) and B (from boric acid) were applied at a time as per treatment combination after field lay out of the experiment and were mixed properly through hand spading.

3.8 Seed sowing

Seeds were sown continuously on 11 November 2007 by hand as uniform as possible in the 30cm apart lines. A strip of the same crop was established around the experimental field as border crop. After sowing the seeds were covered with soil and slightly pressed by laddering.

3.9 Weeding and thinning

Weeds of different types were controlled manually and removed from the field. The weeding and thinning were done after 25 days of sowing, on December 05, 2007. Plant population was kept approximately 220 plant $plot^{-1}$. Care was taken to maintain constant plant population per plot.

3.10 Irrigation

Irrigation was done at three times. The first irrigation was given in the field on December 01, 2007 at 20 days after sowing (DAS) through irrigation channel before flowering. The second irrigation was given at the stage of pod formation (40 DAS), on December 22, 2007. The final irrigation was given at the stage of seed formation (60 DAS), on January 13, 2008.

3.11 Pest management

The crop was infested with cutworm at the seedling stage and application of Dursban 25 EC@ 2.5 ml L^{-1} was done twice on December 05 and 11, 2007. The crop was also infested with aphids (*Lipaphis erysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Syphanon 57 EC @ 2ml L^{-1} water. The insecticide was sprayed thrice, the first January 06, 2007; the second on January 15, 2008 and the last on January 21, 2008. The crop was kept under constant observations from sowing to harvesting.

3.12 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 15 February 2008. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise and expressed on hectare basis. Oven dried seeds were put in desiccators for chemical analysis.

3.13 Collection of experimental data

Ten (10) plants from each plot were selected at random and were tagged for the data collection. Data were collected at harvesting stage. The sample plants were cut down to ground level prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm)
2. Number of primary branch plant^{-1}
3. Number of siliquae plant^{-1}
4. Siliqua length (cm)
5. Number of seeds siliqua^{-1}
6. Weight of 1000 seeds (g)
7. Seed yield (t ha^{-1})
8. Stover yield (t ha^{-1})
9. N, P, K, S and B contents in seed (%)

10. N, P, K, S and B contents in stover (%)

11. Oil content in seed (%)

12. Protein content in seed (%)

13. S and B uptake by (stover + seeds) (kg ha^{-1})

14. N, P, K, S and B contents in post harvest soil.

Library

3.13.1 Plant height

The plant height was measured from the ground level to the top of the panicle. Height of 10 plants from each plot were measured and averaged. It was done at the ripening stage of the crop.

3.13.2 No. of branches $plant^{-1}$

Branches were counted at the ripening stage. Branches of 10 plants from each plot were counted and averaged.

3.13.3 No. of pods $plant^{-1}$

Pods were counted at the ripening stage. Pods of 10 plants from each plot were counted and averaged.

3.13.4 No. of seeds pod^{-1}

It was done after harvesting. At first, number of seeds pod^{-1} were counted. Seeds of 10 pods from each plot were counted randomly and averaged.

3.13.5 Pod length

Length of 10 pods from each plot were counted randomly and averaged after harvesting.

3.13.6 Thousand seed weight

Thousand seed of mustard were counted randomly and then weighed plot wise.

3.13.7 Grain yield

Grains obtained from 1 m^2 area from the center of each unit plot was dried, weighed carefully and then converted into t ha^{-1}.

3.13.8 Stover yield

Straw obtained from each individual plot was dried, weighed carefully and the yield expressed in t ha^{-1}.

3.14 Chemical analysis of the plant and soil samples

3.14.1 Plant sample analysis

The plant samples collected from different treatment combinations were digested with conc. HNO_3 and $HClO_4$ mixture for the determination of total P, K and S.

3.14.1. a) Phosphorous

Phosphorous in the digests were determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.14.1. b) Potassium

Potassium content in plant samples were determined by flame photometer.

3.14.1. c) Sulphur

Sulphur content in the digests were determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspac, 4049).

3.14.1. d) Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4 : $CuSO_4.5H_2O$: Selenium powder in the ratio 100 : 10 : 1, respectively) for the determination of total nitrogen by Micro-Kjeldal method. Total nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.14.2 Soil sample analysis

The soil samples collected from different treatment combinations were chemically analyzed for the determination of N, P, K, S and B.

3.14.2. a) Particle size analysis of soil

Particle size analysis of the soil was done by hydrometer method (Bouyoucos, 1927). The textural class was determined using Marshell's Triangular co-ordinate as designated by USDA (1951).

3.14.2. b) Organic carbon (%)

Soil organic carbon was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973) from the samples collected before sowing and also after harvesting the crop.

3.14.2. c) Organic matter (%)

The organic matter content was calculated by multiplying the percent organic carbon with Van Bemmelen factor 1.724 (Piper, 1942)

% organic matter = % organic carbon × 1.724

3.14.2. d) Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2 conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Selenium powder in the ratio 100 :10 :1, respectively). Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.14.2. e) Available phosphorous (ppm)

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.14.2. f) Available potassium (ppm)

Available potassium in the soil sample was extracted with 1N neutral ammonium acetate and the potassium content was determined by flame photometer.

3.14.2. g) Available sulphur (ppm)

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2$. H_2O (Fox, *et al.*, 1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049). The intensity of turbid was measured by spectrophotometer at 420 nm wavelength.

3.14.2. h) Available boron (ppm)

Available boron (B) content in the soil samples were determined by the method described by Hunter (1984). The extracting agent used was monocalcium phosphate [$CaH_4(PO_4)_2$. H_2O] solution and colour was developed by curcumin solution. The absorbance was read on spectrophotometer at 555 nm wavelength.

3.14.2. i) Soil p^H

The P^H of the soil was determined with the help of a glass electrode p^H meter using soil: water ratio of 1: 2.5 (Jackson, 1973).

3.15 Methods for seed analysis

For determination of total N, P, K, S and B contents in seed the samples were first digested with acid and determination of the elements in the digest were performed either by titration (for N) or by colorimetric methods (for B). For N, digestion was done with conc. H_2SO_4 and digest was distilled following the procedure outlined under soil analysis section (3.14.1.d). While for B, digestion was performed by diacid mixture (HNO_3 and $HClO_4$ in the ratio of 2:1). The amount of the element in the digest was estimated following the procedure described under soil analysis section (3.14.2.h).

3.15.1 Protein content in seed (%)

Protein content in seed was estimated by multiplying N (%) in seed with 6.25.

Total protein (%) = Total N (%) × 6.25.

3.15.2 Oil content (%)

Oil content of mustard was estimated by solvent extraction method with soxhlet apparatus. (As described by South Combe, 1926)

3.16 Total uptake of nutrient by seed + stover (kg ha^{-1})

Total uptake of S and B was determined by adding uptake by seed and uptake by stover.

3.17 Statistical Analysis

The collected data were statistically analyzed by using the ANOVA technique. The test of significance of all parameters was done. The Duncan's Multiple Range Test (DMRT) with Least Significant Difference value was determined with appropriate levels of significance and the means were tabulated. The mean comparison was carried out by DMRT technique (Gomez and Gomez, 1984). The statistical package MSTATC was used for this purpose.

Chapter IV

RESULTS AND DISCUSSION

CHAPTER 4
RESULTS AND DISCUSSION

The results on different yield attributes, yield, oil content and nutrient concentrations in the plants and grains and availability of different nutrients in the soil after harvest of mustard are presented in this chapter.

4.1 Plant height

4.1.1 Effect of sulphur on the plant height of mustard

The effects of sulphur on the plant height of mustard are presented in Table 4.1. Significant variation was observed on the plant height of mustard when the field was fertilized with different doses of sulphur. Among the different doses of sulphur, S_3 (35 kg S ha^{-1}) showed the highest plant height (98.11 cm) and it was closely followed by (95.63 cm) S_2 (25 kg S ha^{-1}) treatment. On the other hand, the lowest plant height (82.53 cm) was observed in the S_0 treatment where no sulphur was applied. It was observed that plant height increased gradually with the increment of sulphur doses. This might be due to higher availability of N P S K and their uptake that progressively enhanced the vegetative growth of the plant. This result is similar with the findings of some other researchers, e.g. Birbal *et al.* (2004) and Singh and Dhiman (2004). Sudhakar *et al.* (2002) found significant increase in plant height of mustard due to the application of 60 kg S ha^{-1}.

Table 4.1 Effect of sulphur on the growth parameters of mustard

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}
S_0	82.53 b	4.72 c	97.13 c	16.43 c
S_1	91.85 a	5.51 b	107.60 bc	20.34 b
S_2	95.63 a	5.97 a	132.30 a	22.09 a
S_3	98.11 a	5.95 a	126.40 ab	22.15 a
LSD	**6.05**	**0.398**	**19.25**	**1.86**
Significance level	**5%**	**5%**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.1.2 Effect of boron on the plant height of mustard

Mustard plants showed significant variation in respect of plant height when boron fertilizers in different doses were applied (Table 4.2). Among the different fertilizer doses, B_2 (2 kg B ha^{-1}) showed the highest plant height (95.56 cm), which was statistically identical with the fertilizer dose B_1 (1 kg B ha^{-1}) and B_3 (4 kg B ha^{-1}). On the contrary, the lowest plant height (86.17 cm) was observed in the treatment where no boron fertilizer was applied.

Table 4.2 Effect of boron on the growth parameters of mustard

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}
B_0	86.17 b	4.85 c	93.35 c	16.87 c
B_1	93.48 a	5.70 ab	111.9 bc	20.11 b
B_2	95.56 a	6.02 a	137.3 a	22.18 a
B_3	92.91 a	5.54 b	120.9 ab	22.68 a
LSD	**6.05**	**0.398**	**19.25**	**1.86**
Significance level	**5%**	**5%**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.1.3 Interaction effect of sulphur and boron on the plant height of mustard

Combined application of different doses of sulphur and boron fertilizers had significant effect on the plant height of mustard (Table 4.3). The lowest plant height (74.43 cm) was observed in the treatment combination of S_0B_0 (No sulphur and No boron). On the other hand, the highest plant height (102 cm) was recorded with S_2B_3 (25 kg S ha^{-1} + 4 kg B ha^{-1}) which was statistically similar with the S_1B_3 (15 kg S ha^{-1} + 4 kg B ha^{-1}) treatment. Pradhan and Sarker (1993) also found similar result by using 20 kg S and 1 kg B ha^{-1}.

Table 4.3 Interaction effect of sulphur and boron on the growth parameters of mustard

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}
S_0B_0	74.43 e	4.11 f	86.00 ef	13.57 g
S_1B_0	80.10 de	4.46 ef	84.53 f	14.57 fg
S_2B_0	89.87 abcd	5.20 bcde	115.00 abcdef	15.67 efg
S_3B_0	85.70 cde	5.10 cde	103.00 cdef	21.93 bcd
S_0B_1	94.20 abc	5.00 de	87.20 ef	15.57 efg
S_1B_1	94.37 abc	5.97 abc	110.90 bcdef	19.57 cde
S_2B_1	91.13 abcd	5.77 abcd	132.90 abcd	22.53 abcd
S_3B_1	87.70 bcde	5.30 bcde	99.30 def	23.70 abc
S_0B_2	86.73 cde	5.13 bcde	86.30 ef	18.60 def
S_1B_2	97.83 abc	6.03 ab	131.10 abcde	22.97 abc
S_2B_2	99.20 abc	6.57 a	154.40 ab	26.30 a
S_3B_2	98.77 abc	5.90 abcd	157.30 a	23.80 abc
S_0B_3	89.30 abcd	5.17 bcde	113.90 abcdef	19.73 cd
S_1B_3	101.60 ab	6.33 a	121.00 abcdef	23.33 abc
S_2B_3	102.00 a	6.53 a	146.80 abc	24.23 ab
S_3B_3	99.47 abc	5.87 abcd	124.00 abcdef	21.30 bcd
LSD	**12.11**	**0.79**	**38.51**	**3.72**
Significance level	**5%**	**5%**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.2 No. of branches plant^{-1}

4.2.1 Effect of sulphur on the No. of branches plant^{-1} of mustard

Significant variation was observed in the number of branches plant^{-1} of mustard when different doses of sulphur were applied (Table 4.1). The highest number of branches plant^{-1} (5.97) was recorded in S_2 (35 kg S ha^{-1}) which was statistically similar with the S_2 (25 kg S ha^{-1}) treatment. The lowest number of branches plant^{-1} (4.72) was recorded in the S_0 treatment where no sulphur was applied. Singh and Dhiman (2004) also found similar results with increasing rate of S.

4.2.2 Effect of boron on No. of branches plant^{-1} of mustard

Different doses of boron fertilizer showed significant variations in respect of number of branches plant^{-1} (Table 4.2). Among the different doses of boron, B_2 (2 kg B ha^{-1}) showed the highest number of branches plant^{-1} (6.02) which was statistically similar with B_1 treatment. On the contrary, the lowest number of branches plant^{-1} (4.85) was observed with B_0, where no boron fertilizer was applied. Dutta *et al.* (1984) also found similar results with the application of 1 kg B ha^{-1}.

4.2.3 Interaction effect of sulphur and boron on the No. of branches plant^{-1} of mustard

The combined effect of different doses of S and B fertilizer on the no. of branches plant^{-1} of mustard was significant (Table 4.3). The highest number of branches plant^{-1} (6.57) was recorded with the treatment combination of S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with the treatment S_1B_3 (15 kg S ha^{-1} + 4 kg B ha^{-1}) and S_2B_3 (25 kg S ha^{-1} + 4 kg B ha^{-1}). On the other hand, the lowest number of branches plant^{-1} (4.11) was found in S_0B_0 treatment (control treatment).

4.3 Number of pods plant^{-1}

4.3.1 Effect of sulphur on the number of pods plant^{-1} of mustard

Significant variation was observed in number of pods plant^{-1} of mustard when different doses of sulphur were applied (Table 4.1). The highest number of pods plant^{-1} (132.3) was recorded in S_2 (25 kg S ha^{-1}) which was statistically similar with the S_3 (35 kg S ha^{-1}) treatment. The lowest number of pods plant^{-1} (97.13) was recorded in the S_0 treatment where no sulphur was applied. Chauhan *et al.* (2002) also found similar results with 20 kg S ha^{-1}.

4.3.2 Effect of boron fertilizers on the number of pods plant^{-1} of mustard

Different doses of boron fertilizers showed significant variations in respect of number of pods plant^{-1} (Table 4.2). Among the different doses of fertilizers, B_2 (2 kg B ha^{-1}) showed the highest number of pods plant^{-1} (137.3) which was statistically similar with the B_3 (4 kg B ha^{-1}) treatment. On the contrary, the lowest number of pods plant^{-1} (93.35) was observed with B_0 where no boron fertilizer was applied. Dutta *et al.* (1984) also found similar results with the application of 1 kg B ha^{-1}.

4.3.3 Interaction effect of sulphur and boron on the number of pods plant^{-1} of mustard

The combined effect of different doses of S and B fertilizer on number of pods plant^{-1} of mustard was significant (Table 4.3). The highest number of pods plant^{-1} (157.3) was recorded with the treatment combination of S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}) treatment. On the other hand, the lowest number of pods plant^{-1} (84.53) was found in S_1B_0 treatment (15 kg S ha^{-1} and No B).

4.4 Number of seeds pod^{-1}

4.4.1 Effect of sulphur on the number of seeds pod^{-1} of mustard

Significant variation was observed in number of seeds pod^{-1} of mustard when different doses of sulphur were applied (Table 4.1). The highest number of seeds pod^{-1} (22.15) was recorded in S_3 (35 kg S ha^{-1}) which was statistically similar with S_2 (25 kg S ha^{-1}). The lowest number of seeds pod^{-1} (16.43) was recorded in the S_0 treatment where no sulphur was applied. Sandeep *et al.* (2002) also found similar results with 20 and 30 kg S ha^{-1}.

4.4.2 Effect of boron on the number of seeds pod^{-1} of mustard

Different doses of boron fertilizers showed significant variations in respect of number of seeds pod^{-1} (Table 4.2). Among the different doses of fertilizer, B_3 showed the highest number of seeds pod^{-1} (22.68) which was statistically similar with the B_2 (2 kg B ha^{-1}) treatment. On the contrary, the lowest number of seeds pod^{-1} (16.87) was observed with B_0, where no boron fertilizer was applied.

4.4.3 Interaction effect of sulphur and boron on the number of seeds pod^{-1} of mustard

The combined effect of different doses of S and B fertilizer on number of seeds pod^{-1} of mustard was significant (Table 4.3). The highest number of seeds pod^{-1} (26.30) was recorded with the treatment combination of S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest number of seeds pod^{-1} (13.57) was found in S_0B_0 treatment (control).

4.5 Pod length (cm)

4.5.1 Effect of sulphur on pod length of mustard

The pod length as affected by different doses of sulphur showed a statistically significant variation (Table 4.4). Among the different doses of S the highest pod length (5.05cm) was observed in S_2 (25 kg S ha^{-1}) which was statistically identical (5.02cm) with S_3 (35 kg S ha^{-1}). The lowest pod length (3.86 cm) was recorded in the S_0 treatment where no S was applied. Probably S supplied the necessary requirements for the proper vegetative growth that helped in obtaining the highest pod length of mustard. Chauhan *et al.* (2002) also found similar results with 20 kg S ha^{-1}.

4.5.2 Effect of boron on pod length of mustard

Application of B fertilizers at different doses showed non significant variation on the pod length of mustard (Table 4.5). Among the different B fertilizer doses, B_2 and B_3 (2 kg and 4 kg B ha^{-1}) showed the highest pod length (4.58 cm).

4.5.3 Interaction effect of sulphur and boron on pod length of mustard

Combined effects of different doses of S and B fertilizers on pod length showed a statistically significant variation (Table 4.6). The highest pod length (5.86 cm) was recorded in the treatment combination of S_1B_3 (15 kg S ha^{-1} + 4 kg B ha^{-1}) which was statistically identical with the treatment combination of S_2B_2 ((25 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest pod length (3.60 cm) was found in S_1B_0.

Table 4.4 Effect of sulphur on yield and yield contributing characters of mustard

Treatments	Pod length (cm)	1000-seed wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0	3.86 b	2.95	1.67 b	3.00 b
S_1	4.00 b	2.98	1.98 a	3.33 b
S_2	5.05 a	3.03	2.03 a	3.73 a
S_3	5.02 a	3.00	2.14 a	3.77 a
LSD	**0.563**	—	**0.252**	**0.342**
Significance level	**5%**	**NS**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.6 Weight of 1000 seed (g)

4.6.1 Effect of sulphur on weight of 1000-seed of mustard

Insignificant variation was observed on the weight of 1000 seed of mustard when different doses of S were applied (Table 4.4). The highest weight of 1000 seed (3.03 g) was recorded in S_2 (25 kg S ha^{-1}). The lowest weight of 1000 seed (2.95 g) was recorded in the S_0 treatment where no S was applied.

4.6.2 Effect of boron on weight of 1000 seed of mustard

Different doses of B fertilizers showed insignificant variations in respect of the weight of 1000 seed (Table 4.5). Among the different doses of B fertilizers, B_2 (2 kg B ha^{-1}) showed the highest weight of 1000 seed (2.99g).On the contrary, the lowest weight of 1000 seed (2.96 g) was observed with B_0 where no B fertilizer was applied.

4.6.3 Interaction effect of sulphur and boron on weight of 1000 seed of mustard

The combined effect of different doses of S and B fertilizer on the weight of 1000 seed of mustard was statistically non significant (Table 4.6). The highest weight of 1000 seed (3.03g) was recorded with the treatment combination of S_2B_2 and S_1B_3. On the other hand, the lowest weight of 1000 seed (2.88 g) was found in S_0B_0 treatment (control).

Table 4.5 Effect of boron on yield and yield contributing characters of mustard

Treatments	Pod length (cm)	1000-seed wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
B_0	4.44	2.96	1.75 b	3.13 b
B_1	4.57	2.97	2.00 ab	3.27 b
B_2	4.58	2.99	2.05 a	3.69 a
B_3	4.58	2.97	1.92 ab	3.71 a
LSD	———	———	**0.252**	**0.342**
Significance level	**NS**	**NS**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.7 Grain yield of mustard (t/ha^{-1})

4.7.1 Effect of S on the grain yield of mustard

Significant variation was observed on the grain yield of mustard when different doses of S were applied (Table 4.4). The highest grain yield of mustard (2.14 t ha^{-1}) was recorded in S_3 (35 kg S ha^{-1}) which was statistically similar with S_1 (15 kg S ha^{-1}) and S_2 (25 kg S ha^{-1}). The lowest grain yield of mustard (1.67 t ha^{-1}) was recorded in the S_0 treatment where no S was applied. These findings are similar with the findings of

some other researchers such as Birbal *et al.* (2004) and Singh and Dhiman (2004). Verma *et al.* (2002) also found similar results with 20 kg S ha^{-1}.

4.7.2 Effect of B on the grain yield of mustard.

Different doses of B fertilizers showed significant variations in respect of grain yield of mustard (Table 4.5). Among the different doses of B fertilizers, B_2 (2 kg B ha^{-1}) showed the highest grain yield of mustard (2.05 t ha^{-1}) which was statistically identical with the B fertilizer dose of B_1 and B_3. On the contrary, the lowest grain yield of mustard (1.758 t ha^{-1}) was observed with B_0 where no B fertilizer was applied. Sen and Farid (2005) also reported that application of 1.5 kg B ha^{-1} produced 37% higher yield over control.

4.7.3 Interaction effect of S and B fertilizers on grain yield of mustard

The combined effect of different doses of S and B fertilizer on the grain yield of mustard was significant (Table 4.6). The highest grain yield of mustard (2.23 t ha^{-1}) was recorded with the treatment combination of S_3B_1 and S_2B_2 which was statistically identical with the fertilizer dose of S_3B_3 and S_1B_1. On the other hand, the lowest grain yield of mustard (1.23 t ha^{-1}) was found in S_0B_0 treatment (No S and No B). Pradhan and Sarker (1993) also found same result by using 20 kg S and 1 kg B ha^{-1}.

Table 4.6 Interaction effects of sulphur and boron on yield and yield contributing characters of mustard

Treatments	Pod length (cm)	1000 seed wt. (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
S_0B_0	3.80 ef	2.88	1.23 d	2.53 d
S_1B_0	3.60 f	2.89	1.73 abcd	2.86 cd
S_2B_0	4.23 bcdf	2.89	1.60 bcd	3.50 bc
S_3B_0	3.83 ef	2.91	2.13 abc	3.13 bcd
S_0B_1	3.96 cdef	2.96	1.56 cd	3.10 bcd
S_1B_1	3.77 ef	2.96	2.16 ab	3.43 bc
S_2B_1	3.90 def	2.93	1.90 abc	3.13 bcd
S_3B_1	4.37 bcdef	2.97	2.23 a	3.66 abc
S_0B_2	4.76 abcdef	2.95	2.06 abc	3.40 bc
S_1B_2	5.03 abcde	3.02	1.90 abc	3.33 bc
S_2B_2	5.47 ab	3.03	2.23 a	3.83 ab
S_3B_2	4.93 abcde	2.99	2.03 abc	4.36 a
S_0B_3	5.23 abc	3.00	2.06 abc	3.50 bc
S_1B_3	5.86 a	3.03	2.13 abc	3.46 bc
S_2B_3	4.73 abcdef	3.00	2.06 abc	4.30 a
S_3B_3	5.20 abcd	2.96	2.20 a	3.83 ab
LSD	**1.12**	——	**0.50**	**0.68**
Significance level	**5%**	**NS**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.8 Stover yield of mustard (t ha^{-1})

4.8.1 Effect of S on the stover yield of mustard

Significant variation was observed on the stover yield of mustard when different doses of S were applied (Table 4.4). The highest stover yield of mustard (3.77 t ha^{-1}) was recorded in S_3 (35 kg S ha^{-1}), which was statistically similar with S_2 (25 kg S ha^{-1}). The lowest stover yield (3.00 t ha^{-1}) was recorded in the S_0 treatment where no S was applied. Verma *et al.* (2002) also found similar results with 20 kg S ha^{-1}.

4.8.2 Effect of B on the stover yield of mustard

Different doses of B fertilizers showed significant variations in respect of stover yield of mustard (Table 4.5). Among the different doses of B fertilizers, B_3 (4 kg B ha^{-1}) showed the highest stover yield (3.71 t ha^{-1}), which was statistically identical (3.69 t ha^{-1}) with the B fertilizer dose of B_2 (2 kg B ha^{-1}). On the contrary, the lowest stover yield (3.13 t ha^{-1}) was observed with B_0, where no B fertilizer was applied.

4.8.3 Interaction effect of S and B on stover yield of mustard

The combined effect of different doses of S and B fertilizers on the stover yield was significant (Table 4.6). The highest stover yield (4.36 t ha^{-1}) was recorded with the treatment combination of S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}) which was statistically identical (4.30 t ha^{-1}) with the fertilizer dose of S_2B_3 (25kg S ha^{-1} + 4 kg B ha^{-1}). On the other hand, the lowest stover yield (2.53 t ha^{-1}) was found in S_0B_0 treatment (No S and No B).

4.9 Total nitrogen concentrations in mustard stover

4.9.1 Effect of S on nitrogen content in mustard stover

Application of S showed significant variation on the nitrogen concentration in mustard stover (Table 4.7). The highest nitrogen concentration in stover (1.153%) was recorded in S_3 (35 kg S ha^{-1}) which was statistically similar with S_2 (25 kg S ha^{-1}) and S_1 (15 kg S ha^{-1}). On the other hand, the lowest nitrogen concentration in stover (1.099%) was recorded in the S_0 treatment where no S was applied.

4.9.2 Effect of B on nitrogen content in mustard stover

The effect of different doses of boron showed statistically significant difference on nitrogen concentration in mustard stover (Table 4.8). The highest nitrogen concentration among the treatments of boron (1.147%) was observed in B_2 (2 kg B ha^{-1}) and B_3 (4 kg B ha^{-1}) treatment which was statistically similar with B_1 (1 kg B ha^{-1}) treatment. The lowest nitrogen concentration 1.095% was observed in B_0 (control condition) treatment.

4.9.3 Interaction effect of S and B on nitrogen concentrations in mustard stover

Significant effect of combined application of different doses of S and B fertilizers on the nitrogen concentration was observed in the stover of mustard (Table 4.9). All the treatment combinations showed statistically similar results of N concentration except S_0B_0 and S_0B_1 treatments.

4.10 Total phosphorus concentrations in mustard stover

4.10. 1 Effect of S on phosphorus content in mustard stover

Application of S showed significant variation in the phosphorus concentration in mustard stover (Table 4.7). The highest phosphorus concentration in stover (0.061%)

was recorded in S_2 (25 kg S ha^{-1}) which was statistically similar with S_1 (15 kg S ha^{-1}) and S_3 (35 kg S ha^{-1}). On the other hand, the lowest phosphorus concentration in stover (0.046%) was recorded in the S_0 treatment where no S was applied.

4.10.2 Effect of B on phosphorus content in mustard stover

The effect of different doses of boron showed statistically significant difference on phosphorus concentration in mustard stover (Table 4.8). The highest phosphorus concentration among the treatments of boron (0.063%) was observed in B_1 (1 kg B ha^{-1}) which was similar with B_2 (2 kg B ha^{-1}) and B_3 (4 kg B ha^{-1}). The lowest phosphorus concentration 0.049% was observed in B_0 treatment.

4.10.3 Interaction effect of S and B on phosphorus concentrations in mustard stover

Insignificant effect of combined application of different doses of S and B fertilizers on the phosphorus concentration was observed in the stover of mustard (Table 4.9). However the highest concentration of phosphorus in the stover (0.065%) was recorded with the S_1B_2 (15 kg S ha^{-1} + 2 kg B ha^{-1}) treatment. On the other hand, the lowest phosphorus concentration (0.040%) in stover was found in S_0B_0 treatment.

Table 4.7 Effect of sulphur on total N P K S and B concentrations in mustard stover

Treatments	Total N %	Total P (%)	Total K (%)	Total S (%)	Total B (%)
S_0	1.099 b	0.046 b	0.69	0.195 d	0.0031
S_1	1.119 ab	0.055 ab	0.74	0.242 c	0.0039
S_2	1.150 a	0.061 a	0.79	0.259 b	0.0056
S_3	1.153 a	0.056 ab	0.80	0.294 a	0.0041
LSD	**0.035**	**0.011**	—	**0.011**	—
Significance level	**1%**	**1%**	**NS**	**1%**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.11 Total potassium concentrations in mustard stover

4.11.1 Effect of S on potassium content in stover

A statistically insignificant variation was observed on potassium concentration in stover of mustard with different doses of sulphur (Table 4.7). However, the highest potassium concentration (0.80%) among the different doses of sulphur was recorded in S_3 (35 kg S ha^{-1}).On the other hand, the lowest potassium concentration (0.69 %) was recorded in the S_0 treatment where no S was applied.

4.11.2 Effect of B on potassium content in mustard stover

The effect of different doses of B fertilizers showed a statistically insignificant variation on the potassium concentration in mustard stover (Table 4.8). The highest potassium concentration (0.82%) among the different doses of B fertilizers was recorded with B_2 treatment. The lowest potassium concentration (0.71 %) was observed in the B_0 treatment.

4.11.3 Interaction effect of S and B on total potassium content in mustard stover

Insignificant effect of combined application of different doses of S and B fertilizers on the potassium concentration was observed in stover of mustard (Table 4.9). The highest concentration (0.86%) of potassium in the stover was recorded with S_2B_3 (25 kg S ha^{-1} + 4 kg B ha^{-1}) and S_3B_3 (35 kg S ha^{-1} + 4 kg B ha^{-1}). On the other hand, the lowest potassium concentration (0.62 %) was found in S_0B_0 treatment.

4.12 Total sulphur concentrations in mustard stover

4.12.1 Effect of S on sulphur content in mustard stover

A statistically significant variation was observed on sulphur concentration in the stover of mustard with different doses of S (Table 4.7). Among the different doses of S the highest sulphur concentration in plant (0.294 %) was recorded in S_3 (35 kg S ha^{-1}) treatment. On the other hand, the lowest sulphur concentration (0.195 %) was recorded in the S_0 treatment where no S was applied.

4.12.2 Effect of B on sulphur content in mustard stover

The effect of different doses of B fertilizers showed a statistically significant variation in the sulphur concentration in stover of mustard (Table 4.8). The highest sulphur concentration (0.275%) in plant among different doses of B fertilizers was recorded

with B_2, which was statistically similar with B_1 (0.265 %). The lowest sulphur concentration (0.222 %) was observed in the treatment B_0 where no B fertilizer was applied.

Table 4.8 Effect of boron on total N P K S and B concentrations in mustard stover

Treatments	Total N %	Total P (%)	Total K (%)	Total S (%)	Total B (%)
B_0	1.095 b	0.049 b	0.71	0.222 b	0.0020
B_1	1.131 a	0.063 a	0.71	0.265 a	0.0033
B_2	1.147 a	0.055 ab	0.82	0.275 a	0.0054
B_3	1.147 a	0.051 ab	0.79	0.227 b	0.0059
LSD	**0.035**	**0.011**	—	**0.011**	—
Significance level	**1%**	**1%**	**NS**	**1%**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.12.3 Interaction effect of S and B on sulphur content in mustard stover

Significant effect of combined application of different doses of S and B fertilizers on the sulphur concentration was observed in stover of mustard (Table 4.9). The highest concentration of sulphur in the stover (0.313 %) was recorded with the highest dose of S and B fertilizers S_3B_3 (35 kg S ha^{-1} + 4 kg B ha^{-1}) which may be due to the higher supply and subsequent assimilation of this element in the plant. On the other hand, the lowest sulphur concentration (0.184 %) was found in S_0B_0 treatment.

4.13 Total boron concentrations in mustard stover

4.13.1 Effect of S on boron content in mustard stover

A statistically insignificant variation was observed on boron concentration in stover of mustard with different doses of S (Table 4.7). Among the different doses of S the highest boron concentration in plant (0.0055 %) was recorded in S_2 (25 kg S ha^{-1}) treatment. On the other hand, the lowest boron concentration (0.0031 %) was recorded in the S_0 treatment where no S was applied.

4.13.2 Effect of B on boron content in mustard stover

The effect of different doses of B fertilizers showed a statistically insignificant variation on the boron concentration in stover of mustard (Table 4.8). However the highest boron concentration in stover (0.0059%) among different doses of B fertilizers was recorded with B_3 treatment. The lowest boron concentration (0.0020 %) was observed in the B_0 treatment where no B fertilizer was applied.

4.13.3 Interaction effect of S and B on boron content in mustard stover

Insignificant effect of combined application of different doses of S and B fertilizers on the boron concentration was observed in stover of mustard (Table 4.9). The highest concentration of boron in the stover (0.0083 %) was recorded with the S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}) treatment. On the other hand, the lowest boron concentration (0.0009 %) was found in S_0B_0 treatment.

Library

Table 4.9 Interaction effect of sulphur and boron on N P K S and B concentrations in mustard stover

Treatments	Total nitrogen (%	Total phosphorus (%)	Total potassium (%)	Total sulphur (%)	Total boron (%)
S_0B_0	1.064 b	0.040	0.62	0.184 e	0.0009
S_1B_0	1.082 ab	0.060.	0.66	0.196 e	0.0030
S_2B_0	1.122 ab	0.046	0.76	0.202 e	0.0038
S_3B_0	1.128 ab	0.040	0.73	0.101 e	0.0048
S_0B_1	1.072 b	0.055	0.72	0.204 e	0.0019
S_1B_1	1.125 ab	0.063	0.69	0.275 bc	0.0033
S_2B_1	1.143 ab	0.056	0.80	0.298 ab	0.0052
S_3B_1	1.136 ab	0.047	0.78	0.194 e	0.0050
S_0B_2	1.122 ab	0.058	0.74	0.240 d	0.0025
S_1B_2	1.157 a	0.065	0.78	0.294 ab	0.0040
S_2B_2	1.161 a	0.064	0.85	0.300 a	0.0075
S_3B_2	1.161 a	0.058	0.82	0.203 e	0.0083
S_0B_3	1.122 ab	0.046	0.73	0.263 c	0.0028
S_1B_3	1.162 a	0.054	0.75	0.298 ab	0.0029
S_2B_3	1.164 a	0.061	0.86	0.302 a	0.0050
S_3B_3	1.162 a	0.040	0.86	0.313 a	0.0057
LSD	**0.071**	—	—	**0.022**	—
Significance level	**1%**	**NS**	**NS**	**1%**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.14 Total nitrogen concentrations in mustard seed

4.14.1 Effect of S on nitrogen content in mustard seed

Application of S showed significant variation on the nitrogen concentration in mustard seed (Table 4.10). The highest nitrogen concentration in seed (3.61%) was recorded in S_3 (35 kg S ha^{-1}), which was statistically similar with S_2 (25 kg S ha^{-1}). On the other hand, the lowest nitrogen concentration in seed (2.89%) was recorded in the S_0 treatment where no S was applied.

4.14.2 Effect of B on nitrogen content in mustard seed

The effect of different doses of boron showed statistically significant difference on nitrogen concentration in mustard seed (Table 4.11). The highest nitrogen concentration among the treatments of boron (3.75%) was observed in B_2 (2 kg B ha^{-1}). The lowest nitrogen concentration (2.99%) was observed in B_0 treatment.

4.14.3 Interaction effect of S and B on nitrogen concentrations in mustard seed

Significant effect of combined application of different doses of S and B fertilizers on the nitrogen concentration was observed in the seed of mustard (Table 4.12). The highest concentration of nitrogen in the seed (3.92%) was recorded with the treatment S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest nitrogen concentration (2.96%) in seed was found in S_0B_0 treatment.

Library

Table 4.10 Effect of sulphur on total N P K S and B concentrations in mustard seed

Treatments	Total N %	Total P (%)	Total K (%)	Total S (%)	Total B (%)
S_0	2.89 c	0.523 b	0.420	0.696 c	0.0042
S_1	3.32 b	0.544 ab	0.355	0.746 bc	0.0058
S_2	3.58 a	0.573 a	0.420	0.760 ab	0.0076
S_3	3.61 a	0.558 ab	0.422	0.807 a	0.0071
LSD	**0.037**	**0.035**	——	**0.050**	——
Significance level	**5%**	**1%**	**NS**	**1%**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.15 Total phosphorus concentrations in mustard seed

4.15. 1 Effect of S on phosphorus content in mustard seed

Application of S showed significant variation on the phosphorus concentration in mustard plant (Table 4.10). The highest phosphorus concentration in seed (0.573%) was recorded in S_2 (25 kg S ha^{-1}), which was statistically similar with S_1 (15 kg S ha^{-1}) and S_3 (35 kg S ha^{-1}). On the other hand, the lowest phosphorus concentration in seed (0.523%) was recorded in the S_0 treatment where no S was applied.

4.15.2 Effect of B on phosphorus content in mustard seed

The effect of different doses of boron showed statistically significant difference in phosphorus concentration in mustard seed (Table 4.11). The highest phosphorus concentration (0.594%) among the treatments of boron was observed in B_2 (2 kg B ha^{-1}). The lowest phosphorus concentration 0.533% was observed in B_1 (1kg B ha^{-1}) treatment which was statistically similar with B_0 treatment.

4.15.3 Interaction effect of S and B on phosphorus concentrations in mustard seed

Significant effect of combined application of different doses of S and B fertilizers on the phosphorus concentration was observed in the seed of mustard (Table 4.12). The highest concentration of phosphorus in the seed (0.656%) was recorded with the treatment S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest phosphorus concentration (0.517%) in seed was found in S_0B_0 treatment.

4.16 Total potassium concentrations in mustard seed

4.16.1 Effect of S on potassium content in seed

A statistically insignificant variation was observed on potassium concentration in seed of mustard with different doses of S (Table 4.10). The highest potassium concentration (0.422%) among the different doses of S was recorded in S_3 (35 kg S ha^{-1}). On the other hand, the lowest potassium concentration in mustard seed (0.420 %) was recorded in the S_0 treatment where no S was applied.

4.16.2 Effect of B on potassium content in mustard seed

The effect of different doses of B fertilizers showed a statistically significant variation on the potassium concentration in mustard seed (Table 4.11). The highest potassium concentration (0.440%) among the different doses of B fertilizers was recorded with B_3 treatment in seed, which was similar with B_2 (0.439%). The lowest potassium concentration (0.337%) in seed was observed in the B_0 treatment.

4.16.3 Interaction effect of S and B on potassium content in mustard seed

Significant effect of combined application of different doses of S and B fertilizers on the potassium concentration was observed in seed of mustard (Table 4.12). The highest concentration of potassium in the seed (0.483%) was recorded with the treatment of S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with all the treatment combinations except S_0B_1.

4.17 Total sulphur concentrations in mustard seed

4.17.1 Effect of S on sulphur content in mustard seed

A statistically significant variation was observed on sulphur concentration in seed of mustard with different doses of S (Table 4.10). Among the different doses of S the highest sulphur concentration in seed (0.807%) was recorded in S_3 (35 kg S ha^{-1}) treatment, which was statistically similar with S_2 (25 kg S ha^{-1}). On the other hand, the lowest sulphur concentration in seed (0.696 %) was recorded in the S_0 treatment where no S was applied.

Table 4.11 Effect of boron on total N P K S and B concentrations in mustard seed

Treatments	Total N %	Total P (%)	Total K (%)	Total S (%)	Total B (%)
B_0	2.99 d	0.536 b	0.337 b	0.702 b	0.0032
B_1	3.27 c	0.533 b	0.401 ab	0.747 ab	0.0049
B_2	3.75 a	0.594 a	0.439 a	0.769 a	0.0079
B_3	3.56 b	0.537 b	0.440 a	0.791 a	0.0087
LSD	**0.037**	**0.036**	**0.071**	**0.050**	———
Significance level	**5%**	**1%**	**1%**	**1%**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.17.2 Effect of B on sulphur content in mustard seed

The effect of different doses of B fertilizers showed a statistically significant variation on the sulphur concentration in seed of mustard (Table 4.11). The highest sulphur concentration in seed (0.791%) among different doses of B fertilizers was recorded with B_3 (4 kg B ha^{-1}) which was statistically similar with B_2 (2 kg B ha^{-1}). The lowest sulphur concentration (0.702 %) in seed was observed in the treatment B_0 where no boron fertilizer was applied.

4.17.3 Interaction effect of S and B on sulphur content in mustard seed

Significant effect of combined application of different doses of S and B fertilizers on the sulphur concentration was observed in seed of mustard (Table 4.12). The highest concentration of sulphur in the seed (0.865%) was recorded with the highest doses of S and B fertilizers which may be due to the higher supply and subsequent

assimilation of this element in the seed and which was similar with S_3B_2 (0.861 %). On the other hand, the lowest sulphur concentration (0.687 %) in seed was found in S_0B_0 treatment.

4.18 Total boron concentrations in mustard seed

4.18.1 Effect of S on boron content in mustard seed

A statistically insignificant variation was observed on boron concentration in seed of mustard with different doses of S (Table 4.10). Among the different doses of S the highest boron concentration in seed (0.0076 %) was recorded in S_2 (25 kg S ha^{-1}) treatment. On the other hand, the lowest boron concentration in seed (0.0042 %) was recorded in the S_0 treatment where no S was applied.

4.18.2 Effect of B on boron content in mustard seed

The effect of different doses of B fertilizers showed a statistically insignificant variation in the boron concentration in seed of mustard (Table 4.11). However the highest boron concentration in seed (0.0087%) among different doses of B fertilizers was recorded with B_3 (4 kg B ha^{-1}). The lowest boron concentration (0.0032 %) in seed was observed in the treatment B_0 where no B fertilizer was applied.

4.18.3 Interaction effect of S and B on boron content in mustard seed

Insignificant effect of combined application of different doses of S and B fertilizers on the boron concentration was observed in seed of mustard (Table 4.12). The highest concentration of boron in the seed (0.0112 %) was recorded with the S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest boron concentration (0.0028 %) in seed was found in S_0B_0 treatment.

Table 4.12 Interaction effect of sulphur and boron on N P K S and B concentration in mustard seed

Treatments	Total nitrogen (%)	Total phosphorus (%)	Total potassium (%)	Total sulphur (%)	Total boron (%)
S_0B_0	2.96 h	0.517 c	0.406 ab	0.687 d	0.0028
S_1B_0	2.97 h	0.520 c	0.380 ab	0.690 d	0.0050
S_2B_0	3.11 f	0.527 c	0.466 a	0.703 cd	0.0046
S_3B_0	3.11 f	0.528 c	0.426 ab	0.706 cd	0.0048
S_0B_1	2.94 h	0.534 c	0.301 b	0.680 d	0.0028
S_1B_1	3.21 e	0.533 c	0.363 ab	0.760 abcd	0.0045
S_2B_1	3.31 d	0.570 bc	0.333 ab	0.761 abcd	0.0077
S_3B_1	3.81 b	0.542 c	0.423 ab	0.785 abcd	0.0084
S_0B_2	3.05 fg	0.556 bc	0.326 ab	0.713 cd	0.0035
S_1B_2	3.45 c	0.544 c	0.433 ab	0.750 bcd	0.0047
S_2B_2	3.92 a	0.656 a	0.483 a	0.766 abcd	0.0110
S_3B_2	3.88 ab	0.537 c	0.440 ab	0.861 ab	0.0112
S_0B_3	3.01 gh	0.534 c	0.316 ab	0.731 cd	0.0037
S_1B_3	3.45 c	0.539 c	0.426 ab	0.772 abcd	0.0057
S_2B_3	3.89 ab	0.625 ab	0.473 a	0.815 abc	0.0083
S_3B_3	3.86 ab	0.536 c	0.473 a	0.865 a	0.0105
LSD	**0.074**	**0.071**	**0.142**	**0.1004**	———
Significance level	**5%**	**1%**	**1%**	**1%**	**NS**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.19 Protein content in mustard seed

4.19.1 Effect of S on protein content in mustard seed

A statistically significant variation was observed in protein content in seed of mustard with different doses of S (Table 4.13). Among the different doses of S the highest protein content in seed (22.55 %) was recorded in S_3 (35 kg S ha^{-1}) treatment, which was statistically similar with S_2 (25 kg S ha^{-1}) treatment. On the other hand, the lowest protein content in seed (18.08 %) was recorded in the S_0 treatment where no S was applied. Singh and Dhiman (2004) also found increased oil content with increasing rate of S.

4.19.2 Effect of B on protein content in mustard seed

The effect of different doses of B fertilizers showed a statistically significant variation on the protein content in seed of mustard (Table 4.14). The highest protein content in seed (23.48%) among different doses of B fertilizers was recorded with B_2 (2 kg B ha^{-1}). The lowest protein content (18.70 %) in seed was observed in the treatment B_0 where no B fertilizer was applied.

4.19.3 Interaction effect of S and B on protein content in mustard seed

Significant effect of combined application of different doses of S and B fertilizers on the protein content was observed in seed of mustard (Table 4.15). The highest protein content in the seed (24.55 %) was recorded with the S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}) treatment which was statistically similar S_3B_1, S_3B_2, S_2B_3 and S_3B_3 treatments . On the other hand, the lowest protein content (18.51%) in seed was found in S_0B_0 treatment.

Table 4.13 Effect of sulphur on protein content, oil content and total uptake of S and B by mustard

Treatments	Protein content (%)	Oil content (%)	Total uptake of S and B ($kgha^{-1}$)	
			sulphur	boron
S_0	18.08 c	40.44 c	16.84 c	0.1994 c
S_1	20.77 b	40.97 b	23.38 b	0.2647 b
S_2	22.33 a	41.49 a	26.38 ab	0.3744 a
S_3	22.55 a	41.23 ab	28.70 a	0.3178 ab
LSD	**0.325**	**0.2676**	**2.633**	**0.065**
Significance level	**1%**	**1%**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.20 Oil content in mustard seed

4.20.1 Effect of S on oil content in mustard seed

A statistically significant variation was observed on oil content in seed of mustard with different doses of S (Table 4.13). Among the different doses of S the highest oil content in seed (41.49 %) was recorded in S_2 (25 kg S ha^{-1}) treatment which was statistically similar with S_3 (35 kg S ha^{-1}) treatment. On the other hand, the lowest oil content in seed (40.44 %) was recorded in the S_0 treatment where no S was applied. Singh *et al.* (2002) reported that application of 20 kg S ha^{-1} increased oil content in mustard over control.

4.20.2 Effect of B on oil content in mustard seed

The effect of different doses of B fertilizers showed a statistically significant variation on the oil content in seed of mustard (Table 4.14). The highest oil content in seed among different doses of B fertilizers (41.82 %) was recorded with B_2 (2 kg B ha^{-1}) which was statistically similar with B_1 (1 kg B ha^{-1}) and B_3 (4 kg B ha^{-1}) treatments.

The lowest oil content (40.39 %) in seed was observed in the treatment B_0 where no B fertilizer was applied. Juel (1980) also reported that application of 2 kg B ha^{-1} significantly increased oil content of mustard.

4.20.3 Interaction effect of S and B on oil content in mustard seed

Significant effect of combined application of different doses of S and B fertilizers on the oil content was observed in seed of mustard (Table 4.15). The highest oil content in the seed (42.48 %) was recorded with the S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}) treatment which was statistically similar with S_3B_2, S_1B_3 and S_2B_3 treatments. On the other hand, the lowest oil content (39.54 %) in seed was found in S_0B_0 treatment.

Table 4.14 Effect of boron on the protein content, oil content and total uptake of S and B by mustard

Treatments	Protein content (%)	Oil content (%)	Total uptake of S and B (kg ha^{-1})	
			sulphur	boron
B_0	18.70 d	40.39 b	18.64 c	0.1561 c
B_1	20.54 c	41.56 a	23.57 b	0.2060 c
B_2	23.48 a	41.82 a	25.61 ab	0.3627 b
B_3	22.22 b	41.57 a	26.69 a	0.4316 a
LSD	**0.325**	**0.2676**	**2.633**	**0.065**
Significance level	**1%**	**5%**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.21 Total uptake of S by mustard (seed + stover)

4.21.1 Effect of S on total uptake of S by mustard (seed + stover)

A statistically significant variation was observed in total uptake of S by mustard with different doses of S (Table 4.13). Among the different doses of S the highest uptake (28.70 kg ha^{-1}) was recorded in S_3 (35 kg S ha^{-1}) treatment which was statistically similar with S_2 (25 kg S ha^{-1}) treatment. On the other hand, the lowest uptake (16.84 kg ha^{-1}) was recorded in the S_0 treatment where no S was applied. Naresh *et al.* (2006) also reported that uptake of S increased significantly up to 40 kg S ha^{-1}.

4.21.2 Effect of B on total uptake of S by mustard (seed + stover)

The effect of different doses of B fertilizers showed a statistically significant variation on the total uptake of S by mustard (Table 4.14). The highest uptake among different doses of B fertilizers was recorded with B_3 (4 kg B ha^{-1}) which was statistically similar with B_2 treatment. The lowest uptake (18.64 kg ha^{-1}) was observed in the treatment B_0 where no B fertilizer was applied.

4.21.3 Interaction effect of S and B on total uptake of S by mustard (seed + stover)

Significant effect of combined application of different doses of S and B fertilizers on the total uptake of S was observed by mustard (Table 4.15). The highest uptake (33.00 kg ha^{-1}) was recorded with the highest combined dose of S and B fertilizers which was statistically similar with S_2B_2 treatment. On the other hand, the lowest uptake (10.37 kg ha^{-1}) was found in S_0B_0 treatment.

4.22 Total uptake of B by mustard (seed + stover)

4.22.1 Effect of S on total uptake of B by mustard (seed + stover)

A statistically significant difference was observed on total uptake of B by mustard with different doses of S (Table 4.13). Among the different doses of S the highest uptake (0.374 kg ha^{-1}) was recorded in S_2 (25 kg S ha^{-1}) treatment. On the other hand, the lowest uptake (0.199 kg ha^{-1}) was recorded in the S_0 treatment where no S was applied.

4.22.2 Effect of B on total uptake of B by mustard (seed + stover)

The effect of different doses of B fertilizers showed a statistically significant variation in the total uptake of B by mustard (Table 4.14). The highest uptake among different doses of B fertilizers (0.431 kg ha^{-1}) was recorded with B_3 (4 kg B ha^{-1}) treatment. The lowest uptake (0.156 kg ha^{-1}) was observed in the treatment B_0 where no B fertilizer was applied. Chakravarty *et al.* (1979) also reported that B uptake significantly increased with increasing level of boron.

4.22.3 Interaction effect of S and B on total uptake of B by mustard (seed + stover)

Significant effect of combined application of different doses of S and B fertilizers on the total uptake of B was observed by mustard (Table 4.15). The highest uptake (0.605 kg ha^{-1}) was recorded with the S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}) treatment which was statistically similar with S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest uptake (0.1620 kg ha^{-1}) was found in S_1B_0 treatment.

Table 4.15 Interaction effects of sulphur and boron on protein content, oil content and total uptake of S and B by mustard

Treatments	Protein content (%)	Oil content (%)	Total uptake of S and B (kg ha^{-1})	
			sulphur	boron
S_0B_0	18.51 f	39.54 e	10.37 g	0.1753 f
S_1B_0	18.90 ef	40.42 de	17.52 ef	0.1620 f
S_2B_0	19.46 e	40.88 bcd	17.93 ef	0.2043 ef
S_3B_0	19.44 de	40.78 bcd	21.56 def	0.2560 def
S_0B_1	18.41 f	40.48 cde	16.26 f	0.1067 f
S_1B_1	20.11 cd	40.94 abcd	26.38 bcd	0.2193 ef
S_2B_1	20.69 c	40.98 abcd	24.57 bcd	0.3473 cde
S_3B_1	23.86 a	41.04 abcd	26.31 bcd	0.3853 bcd
S_0B_2	19.06 ef	40.90 bcd	22.97 cde	0.1633 f
S_1B_2	21.56 b	41.07 abc	24.09 cd	0.2213 ef
S_2B_2	24.55 a	42.48 a	30.58 ab	0.5073 ab
S_3B_2	24.16 a	41.68 ab	26.28 bcd	0.6057 a
S_0B_3	18.84 ef	40.92 abcd	24.95 bcd	0.1790 f
S_1B_3	21.59 b	41.53 ab	26.29 bcd	0.2213 ef
S_2B_3	24.18 a	41.42 ab	28.25 abc	0.3917 bcd
S_3B_3	24.11 a	40.94 abcd	33.00 a	0.4793 abc
LSD	**0.651**	**0.535**	**5.265**	**0.129**
Significance level	**1%**	**5%**	**5%**	**5%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.23 Effect of sulphur on organic carbon, nutrient status and p^H of the post harvest soil of mustard field

4.23.1 Effect of sulphur on organic carbon content in the post harvest soil of mustard field

Statistically insignificant variation was observed on organic carbon content of the post harvest soil of mustard field with different doses of S (Table 4.16). Organic carbon contents in all the doses of sulphur were more or less same.

4.23.2 Effect of sulphur on total nitrogen content in the post harvest soil of mustard field

A statistically insignificant variation was observed on nitrogen concentration in post harvest soil of mustard with different doses of S (Table 4.16). Considering the different doses of S the highest nitrogen concentration in soil (0.094 %) was recorded in S_2 (25 kg S ha^{-1}). On the other hand, the lowest nitrogen concentration in soil (0.084%) was recorded in the S_0 treatment where no S was applied.

4.23.3 Effect of sulphur on available phosphorus content in the post harvest soil of mustard field

A statistically significant variation was observed in phosphorus concentration in soil of mustard field with different doses of S (Table 4.16). Considering the different doses of S the highest phosphorus concentration in soil (20.34 ppm) was recorded in S_2 (25 kg S ha^{-1}). On the other hand, the lowest phosphorus concentration in soil (17.69 ppm) was recorded in the S_1 treatment which was statistically similar with S_0 where no S was applied.

4.23.4 Effect of sulphur on available potassium content in the post harvest soil of mustard field

A statistically significant variation was observed on potassium concentration in soil of mustard with different doses of S (Table 4.16). Considering the different doses of S the highest potassium concentration in soil (53.83 ppm) was recorded in S_2 (25 kg S ha^{-1}). On the other hand, the lowest potassium concentration in soil (47.33ppm) was recorded in the S_1 treatment which was statistically similar with S_0 where no S was applied.

Table 4.16 Effect of S on organic carbon, total N, available P, available K, available S, available B content and p^H of the post harvest soil

Treatments	Org. carbon (%)	Total N (%)	Avail. P (ppm)	Avail. K (ppm)	Avail. S (ppm)	Available B (ppm)	Soil P^H
S_0	0.73	0.0848	17.84 c	48.17 c	17.57 d	0.650 c	6.15 a
S_1	0.75	0.0921	17.69 c	47.33 c	19.53 c	0.852 b	6.11 ab
S_2	0.75	0.0941	20.34 a	53.83 a	25.45 b	1.121 a	6.10 ab
S_3	0.74	0.0929	19.85 b	52.00b	30.40 a	1.158 a	6.03 b
LSD	—	—	**0.460**	**1.764**	**0.740**	**0.614**	**0.112**
Significance level	**NS**	**NS**	**1%**	**1%**	**1%**	**1%**	**1%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.23.5 Effect of sulphur on available sulphur content in the post harvest soil of mustard field

A statistically significant variation was observed on sulphur concentration in the post harvest soil of mustard with different doses of S (Table 4.16). Considering the different doses of S the highest sulphur concentration in soil (30.40 ppm) was recorded in S_3 (35 kg S ha^{-1}) treatment. On the other hand, the lowest sulphur concentration in soil (17.57ppm) was recorded in the S_0 treatment where no S was applied.

4.23.6 Effect of sulphur on available boron content in the post harvest soil of mustard field

A statistically significant variation was observed on boron concentration in the post harvest soil of mustard with different doses of S (Table 4.16). Considering the

different doses of S the highest boron concentration in soil (1.158 ppm) was recorded in S_3 (35 kg S ha^{-1}) treatment which was statistically similar to S_2 (25 kg S ha^{-1}). On the other hand, the lowest boron concentration in soil (0.650 ppm) was recorded in the S_0 treatment where no S was applied.

4.23.7 Effect of sulphur on pH in the post harvest soil of mustard field

A statistically significant variation was observed in the soil pH of the post harvest soil of mustard field with different doses of S (Table 4.16). Considering the different doses of S the highest pH (6.15) in the post harvest soil was recorded in S_0 treatment which was statistically similar with S_1 and S_2 treatments. On the other hand, the lowest pH in post harvest soil (6.03) was recorded in the S_3 treatment where 35 kg S ha^{-1} was applied which indicated a slight increase in the acidity of the soil with the highest dose of S applied.

4.24 Effect of boron on the organic carbon, nutrient status and p^H of the post harvest soil of mustard field

4.24.1 Effect of boron on organic carbon content in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically insignificant variation on the organic carbon content in the post harvest soil of mustard field (Table 4.17). No observable variation was observed in the organic carbon content of the post harvest soil due to the application of various doses of boron.

4.24.2 Effect of boron on total nitrogen content in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically insignificant variation in the nitrogen concentration in post harvest soil (Table 4.17). Among the treatments, B_2 (2 kg B ha^{-1}) showed the highest nitrogen concentration (0.094 %) in soil. The lowest nitrogen concentration (0.084 %) in soil was observed in the treatment B_0 where no B fertilizer was applied.

4.24.3 Effect of boron on available phosphorus content in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically significant variation on the phosphorus concentration in the soil of mustard field after harvest (Table 4.17). Among the different treatments B_2 (2 kg B ha^{-1}) showed the highest phosphorus concentration (20.87 ppm) which was statistically similar with B_3 (4 kg B ha^{-1}) treatment. The lowest phosphorus concentration (16.63 ppm) in post harvest soil was observed in the treatment B_0 where no B fertilizer was applied.

4.24.4 Effect of boron on available potassium content in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically significant difference on the potassium concentration in soil of mustard field (Table 4.17). Among the different treatment of fertilizer doses, B_1 (2 kg B ha^{-1}) showed the highest potassium concentration (53.08 ppm) in post harvest soil. The lowest potassium concentration (48.50 ppm) in post harvest soil was observed in the B_0 treatment.

4.24.5 Effect of boron on available sulphur content in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically significant difference in the sulphur concentration in soil of mustard field (Table 4.17). Among the different fertilizer doses, B_1 (1 kg B ha^{-1}) showed the highest sulphur concentration (25.33 ppm) in soil which was statistically similar with B_2 and B_3 treatments. The lowest sulphur concentration (17.65 ppm) in soil was observed in the treatment B_0 where no B fertilizer was applied.

Table 4.17 Effect of boron on organic carbon, total N, available P, available K, available S, available B content and p^H of the post harvest soil

Treatments	Org. carbon (%)	Total N %	Avail. P (ppm)	Avail. K (ppm)	Avail. S (ppm)	Available B (ppm)	Soil p^H
B_0	0.73	0.0848	16.63 c	48.50 c	17.65 b	0.342 d	6.14 a
B_1	0.76	0.0911	17.46 b	53.08 a	25.33 a	0.583 c	6.12 a
B_2	0.76	0.0947	20.87 a	48.75 c	24.88 a	1.147 b	6.10 a
B_3	0.75	0.0929	20.76 a	51.00 b	25.09 a	1.710 a	6.08 b
LSD	—	—	**0.460**	**1.76**	**0.740**	**0.0614**	**0.112**
Significance level	**NS**	**NS**	**1%**	**1%**	**1%**	**1%**	**1%**

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.24.6 Effect of boron on available boron content in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically significant variation on the boron concentration in the post harvest soil of mustard field (Table 4.17). Among the different fertilizer doses, B_3 (4 kg B ha^{-1}) showed the highest boron concentration (1.710 ppm) in soil, which was statistically different from other treatments. The lowest boron concentration (0.342 ppm) in soil was observed in the treatment B_0 where no B fertilizer was applied.

4.24.7 Effect of boron fertilizers on pH in the post harvest soil of mustard field

The effect of different doses of boron fertilizers showed a statistically significant variation in the pH of the post harvest soil of mustard field (Table 4.17). Among the different doses of B fertilizer, B_0 showed the highest value of soil pH (6.14). The lowest pH in the soil sample (6.08) was observed in the treatment B_3 where 4 kg B ha^{-1} was applied.

4.25 Interaction effect of sulphur and boron on organic carbon, nutrient status and p^H of the post harvest soil of mustard field

4.25.1 Interaction effect of sulphur and boron on the organic carbon of the post harvest soil of mustard field

Insignificant effect of combined application of different doses of S and B fertilizer was observed on the organic carbon content in the post harvest soil of mustard field (Table 4.18). No appreciable change on the organic carbon content of the post harvest soil was observed with the combined application of S and B at various treatments.

4.25.2 Interaction effect of sulphur and boron on total nitrogen content of the post harvest soil of mustard field

Insignificant effect of combined application of different doses of S and B fertilizer on the nitrogen concentration was observed in post harvest soil of mustard field (Table 4.18). No observable variation was observed on the N content with different S and B treatment combinations in the post harvest soil of the mustard field.

4.25.3 Interaction effect of sulphur and boron on available phosphorus content of the post harvest soil of mustard field

Significant effect of combined application of different doses of S and B fertilizers on the phosphorus concentration was observed in the post harvest soil of mustard field (Table 4.18). The highest phosphorus concentration (22.68 ppm) was recorded in the treatment combination of S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}) in the post harvest soil which was statistically similar with S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest phosphorus concentration (15.45 ppm) in soil was found in S_1B_0 (15 kg S ha^{-1} + No B) treatment.

4.25.4 Interaction effect of sulphur and boron on available potassium content of the post harvest soil of mustard field

Significant effect of combined application of different doses of S and B fertilizers on the potassium concentration was observed in post harvest soil of mustard field (Table 4.18). The highest potassium concentration (60.0ppm) was recorded in the treatment combination of S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with S_1B_3 (15 kg S ha^{-1} + 4 kg B ha^{-1}) treatment. On the other hand, the lowest potassium concentration (45.0 ppm) in the post harvest soil was found in S_0B_0 treatment.

Table 4.18 Interaction effects of sulphur and boron on organic carbon, total N, available P, available K, available S, available B contents and p^H of the post harvest soil

Treat-ments	Organic carbon (%)	Total nitrogen (%	Available phosphorus (ppm)	Available potassium (ppm)	Available sulphur (ppm)	Available boron (ppm)	p^H
S_0B_0	0.72	0.084	16.20 fg	45.00 e	16.27 k	0.333 fg	6.27 a
S_1B_0	0.71	0.075	15.45 g	49.67 cd	16.68 jk	0.460 ef	6.14 ab
S_2B_0	0.74	0.089	20.16 de	52.00 bc	17.16 ijk	0.600 d	6.12 ab
S_3B_0	0.71	0.088	19.57 e	46.00 de	20.16 g	1.177 c	6.16 ab
S_0B_1	0.73	0.085	15.44 g	46.00 de	16.78 ijk	0.366 fg	6.17 ab
S_1B_1	0.79	0.096	15.62 g	51.00 c	18.33 hi	0.580 de	6.09 ab
S_2B_1	0.78	0.095	19.92 de	46.00 de	23.76 f	1.137 c	6.03 ab
S_3B_1	0.75	0.091	19.79 de	46.33 de	19.27 gh	1.360 b	6.12 ab
S_0B_2	0.74	0.086	19.33 e	55.00 b	18.14 hij	0.306 g	6.14 ab
S_1B_2	0.77	0.097	16.79 f	52.00 bc	27.83 de	0.656 d	6.14 ab
S_2B_2	0.77	0.097	22.68 a	48.33 cde	29.19 cd	1.367 b	6.11 ab
S_3B_2	0.78	0.053	22.54 a	60.00 a	33.88 a	2.153 a	6.05 ab
S_0B_3	0.76	0.082	15.56 g	48.00 cde	18.98 gh	0.363 fg	6.03 ab
S_1B_3	0.75	0.095	21.99 ab	59.67 a	26.62 c	0.636 d	6.07 ab
S_2B_3	0.76	0.097	20.71 cd	48.67 cde	29.40 c	1.483 b	6.02 ab
S_3B_3	0.74	0.096	21.15 bc	51.67 bc	34.33 b	2.150 a	5.95 b
LSD	———	———	0.920	3.52	1.481	0.123	0.224
Significance level	NS	NS	1%	1%	1%	1%	1%
Initial soil	**0.68**	**0.0820**	**13.42**	**45.00**	**23.74**	**0.3800**	**6.16**

In a column, figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.25.5 Interaction effect of sulphur and boron on available sulphur content of the post harvest soil of mustard field

Significant effect of combined application of different doses of S and B fertilizers on the sulphur concentration was observed in post harvest soil of mustard field (Table 4.18). The highest sulphur concentration (33.88 ppm) was recorded in the treatment combination of S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}). On the other hand, the lowest sulphur concentration (16.27 ppm) in soil sample was found in S_0B_0 treatment where no sulphur and boron fertilizer was applied.

4.25.6 Interaction effect of sulphur and boron on available boron content of the post harvest soil of mustard field

Significant effect of combined application of different doses of S and B fertilizers on the boron concentration was observed in soil of mustard field (Table 4.18). The highest boron concentration (2.15 ppm) was recorded in the treatment combinations of S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}) S_3B_3 ((35 kg S ha^{-1} + 4 kg B ha^{-1}) in the post harvest soil. On the other hand, the lowest boron concentration (0.333 ppm) in the post harvest soil was found in S_0B_0 treatment.

4.25.7 Interaction effect of sulphur and boron on p^H of the post harvest soil of mustard field

Significant effect of combined applications of different doses of S and B fertilizers on the pH of post harvest soil was observed in the field of mustard (Table 4.18). The highest value of soil pH (6.27) was recorded in the treatment combination of S_0B_0 which was statistically similar with all other treatment combinations of sulphur and boron except S_3B_3 (lowest). Combined application of S and B fertilizers at high doses showed decrease pH value of the post harvest soil.

Chapter V

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

An experiment was conducted at the Sher-e-Bangla Agricultural University Farm Dhaka 1207 (Tejgaon series under AEZ No.28) during the *rabi* season of 2007 to study the "Interaction effect of sulphur and boron on the growth, yield, chemical composition and oil content of mustard". The soil was silty clay loam in texture having pH 6.16 and organic carbon content of 0.68%. Two factor randomized complete block design was followed with 16 treatments having unit plot size of 2m x 2m ($4m^2$) and replicated thrice. Two factors were sulphur and boron. The treatments were S_0B_0 control (No sulphur + No boron), S_1B_0 (15 kg S ha^{-1} + No boron), S_2B_0 (25 kg S ha^{-1} + No boron), S_3B_0 (35 kg S ha^{-1} + No boron), S_0B_1 (No sulphur + 1 kg B ha^{-1}), S_1B_1 (15 kg S ha^{-1} + 1 kg B ha^{-1}), S_2B_1 (25 kg S ha^{-1} + 1 kg B ha^{-1}), S_3B_1 (35 kg S ha^{-1} + 1 kg B ha^{-1}), S_0B_2 (No sulphur + 2 kg B ha^{-1}), S_1B_2 (15 kg S ha^{-1} + 2 kg B ha^{-1}), S_2B_2 (25 kg S ha^{-1} + 2 kg B ha^{-1}), S_3B_2 (35 kg S ha^{-1} + 2 kg B ha^{-1}), S_0B_3 (No sulphur + 4 kg B ha^{-1}), S_1B_3 (15 kg S ha^{-1} + 4 kg B ha^{-1}), S_2B_3 (35 kg S ha^{-1} + 4 kg B ha^{-1}) and S_3B_3 (35 kg S ha^{-1} + 4 kg B ha^{-1}).

Recommended blanket doses of N, P, K and Zn (110 kg N from urea, 35 kg P from TSP, 40 kg K from MP and 4 kg Zn ha^{-1} from ZnO, respectively) were applied.

The whole amounts of TSP, MP, Zinc oxide and half of the urea fertilizer were applied as basal dose during final land preparation. The remaining half of urea was top dressed after 20 - 22 days of germination (before flowering). The required amounts of S (from gypsum) and B (from boric acid) were applied at a time as per

treatment combination after field lay out of the experiment and were mixed properly through hand spading.

Mustard seeds were sown on 11th November 2007 and the crop was harvested on 15th February 2008. The data were collected plot wise for plant height (cm), number of primary branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, pod length (cm), weight of 1000-seed (g), grain yield (t ha^{-1}) and stover yield (t ha^{-1}) .

The post harvest soil samples from 0-15 cm depth plot wise were collected and analyzed for pH, organic carbon, N, P, K, S and B contents. Seed and stover samples were also chemically analyzed for total N, P, K, S and B contents. Protein content, oil content and total uptake of S and B were also determined. All the data were statistically analyzed following F-test and the mean comparison was made by DMRT. The results of the experiment are stated below.

Plant height was significantly affected by different levels of S and B. Plant height increased with increasing levels of S and B individually. The individual application of S @ 35 kg ha^{-1}(S_3) produced the tallest plant (98.11 cm), whereas application of B @ 2 kg ha^{-1} produced the tallest plant of 95.56 cm height. The tallest plant (102.0 cm) was found in S_2B_3 treatment, which was higher over control treatment (74.43cm).

The individual application of S and B showed positive effect on the number of branches per plant, number of siliquae per plant, number of seeds per siliqua, weight of 1000 seed, grain yield and stover yield. All the plant characters increased with increasing levels of S and B up to higher level except 1000 seed weight.

Like all other plant characters, grain yield of mustard was influenced significantly due to application of S and B. Grain yield increased with increasing levels of S and B up to certain level. The highest grain yield (2.14 t ha^{-1}) was found in plants receiving S @ 35 kg ha^{-1} and the lowest was recorded in S_0 treatment. The individual application of B @ 2 kg ha^{-1} produced the highest amount of grain yield (2.05 t ha^{-1}). The combined application of S and B had positive effect on grain yield of mustard. The highest grain yield of mustard was recorded in S_3B_1 treatment followed by S_2B_2 which was statistically identical with each other. The lowest yield was recorded in S_0B_0 treatment. Combined application of S @ 25 kg ha^{-1} and B @ 2 kg ha^{-1} produced higher grain yield as compared to control treatment significantly.

Protein content in seeds of mustard was significantly increased due to application of S and B. The trend of variation in protein content was similar to that of N content because protein content was calculated directly from the values of N content in seeds. The range of protein content in seeds varied from 18.51% in S_0B_0 to 24.55% in S_2B_2 treatment. Application of S @ 25 kg ha^{-1} and B @ 2 kg ha^{-1} produced higher protein content in seeds as compared to control treatment (S_0B_0).

Oil content in seeds of mustard was significantly increased due to application of S and B. The range of oil content in seeds varied from 39.54% in S_0B_0 to 42.48% in S_2B_2 treatment. Application of S @ 25 kg ha^{-1} and B @ 2 kg ha^{-1} produced higher oil content in seeds as compared to control treatment (S_0B_0).

Nutrient contents (N, P, K, S and B) in stover were positively affected due to S and B fertilization. The interaction effect of S and B was also found remarkable. The N, P,

K, S and B content in stover varied from 1.06% in S_0B_0 treatment to 1.164% in S_2B_3 treatment, 0.040% in S_0B_0 treatment to 0.065% in S_1B_2 treatment, 0.620% in S_0B_0 treatment to 0.860% in S_3B_3 treatment, 0.184% in S_0B_0 treatment to 0.313% in S_3B_3 and 0.0009% in S_0B_0 to 0.0083 % in S_3B_2 treatment, respectively. Nitrogen (N), K, B and S contents in stover increased with increasing levels of S and B up to certain level.

Nutrient contents (N, P, K, S and B) in seeds were positively affected due to S and B fertilization. The interaction effect of S and B was also found remarkable. The N, P, K, S and B content in seeds varied from 2.96% in S_0B_0 treatment to 3.92% in S_2B_2 treatment, 0.517% in S_0B_0 treatment to 0.656% in S_2B_2 treatment, 0.301% in S_0B_1 treatment to 0.483% in S_2B_2 treatment, 0.687% in S_0B_0 treatment to 0.865% in S_3B_3 and 0.0028% in S_0B_0 to 0.0112% in S_3B_2 treatment, respectively. Nitrogen (N), K, B and S contents in seeds also increased with increasing level of S and B up to certain level.

Total nutrient uptake by seed + stover was also affected by S and B fertilization. Total uptake of S and B increased with increasing levels of S up to 35 kg ha^{-1}. Total uptake of S and B also increased with increasing level of B up to 4 kg ha^{-1}. Sulphur uptake increased with increasing levels of S up to higher level. The highest sulphur uptake (28.70 kg ha^{-1}) was recorded with the application of S @ 35 kg ha^{-1}, which was higher as compared to control. On the other hand, boron uptake also increased with increasing levels of B up to higher level. The highest boron uptake (0.431kg ha^{-1}) was recorded with the application of B @ 4 kg ha^{-1}, which was higher as compared to control. The combined effect of S and B on nutrient uptake was significant. The

maximum uptake of B (0.605 kg ha^{-1}) and S (33.0 kg ha^{-1}) was found in S_3B_2 and S_3B_3 treatment, respectively. The minimum uptake was recorded in S_0B_0 treatment. From the findings it was observed that application of S and B accumulated higher amount of nutrients as compared to single application of S or B.

Nutrient content in post harvest soil was also influenced by different levels of S and B application. The total N, available P, available K, available S and available B of post harvest soil varied from 0.075 to 0.097%, 15.45 to 22.68 ppm, 45.0 to 60.0 ppm, 16.27 to 33.88 ppm and 0.333 to 2.15 ppm, respectively due to combined application of S and B at different levels. The addition of S and B not only increased the yield but also protect the soil from total exhaustion of nutrients.

Considering all the parameters studied the following conclusion may be drawn:-

- Significantly higher growth and yield performance, protein content and oil content of mustard was observed by the S_2B_2 treatment i.e., by the combined application of sulphur and boron fertilizers @ 25 kg S ha^{-1} and 2 kg B ha^{-1}.

Based on the results of the present study, the following recommendation may be drawn:-

- The combined application of sulphur and boron fertilizers @ 25 kg S ha^{-1} and 2 kg B ha^{-1} may be done in Tejgaon series under AEZ No.28 to get higher yield, protein and oil content of mustard and also to maintain soil fertility and productivity than their individual applications.

However, to reach a specific conclusion and recommendation, more research work on mustard should be done in different Agro-ecological zones of Bangladesh.

CHAPER VI
REFERENCES

CHAPTER VI
REFERENCES

Abdin, M. Z., Khan, N., Khan, I., Israr, M. and Jamal, A. (2003). Nitrogen and sulphur interaction in relation to yield and quality attributes of rapeseed-mustard. Centre for Biotechnology, Faculty of Science, Hamdard University, New Delhi, India. **5** (3/4): 35-41.

Agarwala, S. C., Sharma, P. N., Chatterjee, C. and Sharma, C. P. (1981). Development and enzyme changes during pollen development in boron deficient plants. *J. plant Nutr.* **3**:329-336.

Ali, M. M., Ali, M. I., Canada, M. C. and Topder, B. K. (1988). Fertilization on an elite mustard mutant (BINA-1) in two soils of Bangladesh. *Bangladesh J. Nucl. Agric.* **4**:37 - 47.

Ali, M.H., Zaman, S.M. H. and Hossain, S. M.A. (1994). Variation in yield, oil and protein content of rapeseed (*Brassica compestries*) in relation to levels of nitrogen, sulphur and plant density. *Indian J. Agron.* **41**(2): 290-295.

Amar, S. and Meena, N. L. (2003). Effect of nitrogen and sulphur levels on the oil and protein yield of mustard (*Brassica juncea*). *Annals of Agric. Res.* **24** (2): 368-371.

Amin, M., Islam, M. F. and Haque, M. M. (1994). Effect of sulphur on different varieties of mustard in Old Himalayan Piedmont Soils. *Bangladesh J. Agril. Res.* **19** (1): 80-84.

Anonymous. (2006) Bangladesh Bureau of Statistics. Monthly Statistical Bulletin of Bangladesh. January, Statistics Div., Ministry of Planning, Govt. People's Repub. Bangladesh. 54.

Banuels, G. S., Meek, D. W. and Hoffman, G. J. (1990). The influence of Selenium, salinity and boron on selenium uptake in wild mustard. *Plant and soil.* **127** (2): 201-206.

BARI (Bangladesh Agricultural Research Institute). (1982). Annual Report for 1981-82. Bangladesh Agrl. Res. Inst., Joydebpur, Gazipur, p.32.

BARI (Bangladesh Agricultural Research Institute). (1985). Annual Report for 1984-85. Bangladesh Agrl. Res. Inst., Joydebpur, Gazipur, p.32.

BBS (2004). Statistical Pocket Book of Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh p. 28.

BBS (2005). Statistical Year Book of Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh p. 149.

Bharati, V. and Prasad, U. K. (2003). Effect of irrigation and sulphur on growth and yield of Indian mustard (*Brassica juncea*). *Indian J. Agric. Sci.* **73** (1): 38-40.

Bilsborrow P. E., Evans E. J., Milford G. F. J., Fieldsend J. K. (1995). The effects of S and N on the yield and quality of oilseed rape in the U.K. 9th Inter. Rapeseed Congress, Cambridge, 280-283.

Birbal, S., Vivek, K. and Nema, M.L. (2004). Response of mustard, *Brassica juncea* (L.) Czern and Coss. to phosphorus and sulphur levels in rice lowlands. *J. Oilseeds. Res.* **21** (1): 181-182.

Bouyoucos, G. J. (1927). The hydrometer as a new method for the mechanical analysis of soils. *Soil Sci.* **23**: 343-353.

Brajendra, S. and Shukla, L.M. (2004). Effect of sulphur levels on dry matter yield of mustard in Alfisols and Ultisols of Jharkhand. *Indian J. Hill-Farming.* **17** (1/2): 81-85.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* **59**: 39-45.

Chakravarty, S. K., Sinha, H. and Singh, K. P. (1979). Note on boron nutrition of cereals and legumes in sand culture study. *Indian J. Agric. Sci.* **49** (5): 382-383.

Chatterjee, B. N., Gosh, R. K. and Chakraborty, P. K. (1985). Response of mustard to sulphur and micronutrient. *Indian J. Agron.* **30** (1): 75-80.

Chaudhury, S. K., Gogulwar, N. M. and Singh, A. K. (1991). Effect of nitrogen and sulphur on seed yield and oil content 'varuna' mustard *(Brassica juncea). Indian J. Agron.* **37** (4): 839-840.

Chauhan, Y. S., Behi, R. K. and Kumar, P. (2002). Association of some physiological determinants with seed yield of toria. *J. Oilseeds Res.* **12**: 174-182.

Dixit, M. L. and Shukla, U. C. (1984). Effect of boron, sulphur and zinc at different phosphorus and moisture levels on yield of mustard (*Brassica juncea*). *J. Indian Soc. Soil Sci.* **32** (2): 186-188.

Dongarkar, K. P., Pawar, W.S., Khawale, V.S., Khutate, N.G. and Gudadhe, N. N. (2005). Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea* L.). J. Soils and Crops. **15** (1): 163-167.

Dubey, O. P. and. Khan, R. A (1991). Effect of nitrogen and sulphur on dry matter, grain yield and nitrogen content of different growth stages of mustard (*Brassica juncea*) under irrigated vertisol. *Indian J. Agron.* **38** (2): 270-276.

Dugger, W. M. (1983). Boron in plant metabolism. In Encydopedia of plant physiol. New series (A. Lauchli and R.L. Bieleski, Eds.) Springer- Verlag, Berlin. New York. **15**: 626-650.

Dutta, R. K. and Uddin, M. (1983). A study on the growth and physiology of mustard in relation to boron supply. In Proc. Of the 8th Bangladesh Sci. Conf. Dhaka, Bangladesh. Bangladesh Assoc. Advan. Sci. p. 101.

Dutta, R. K., Uddin, M. and Rahman, L. (1984). Productivity of mungbean, rice and mustard in relation to boron in Brahmaputra Floodplain soils. *Bangladesh J. Soil Sci.* **20**: 77-83.

Dwivedi, G. K., Madhu, D. and Pal, S. S. (1990). Modes of application of micronutrients in soil in soyabean - wheat crop sequence. *J. Indian Soc. Soil Sci.* **38** (5):458 - 463.

Erikson, M. (1979). Effect of boron on nectar production and seed setting of red clover (*Trifolium pratense*). *Swed. J. Agric. Res.* **9**: 37-41.

Evans E. J., Bilsborrow P. E., Zhao F. J. and Syers J. K. (1991). The sulphur nutrition of winter oilseed rape in Northern Britain. 8th Inter. Rapeseed Congress, Saskatoon, 542-546.

FAO (Food and Agriculture Organization) (2006). Production Yearbook. Vol. **55**.p. 123.

FAO, (2004). FAO Production Year Book. Food and Agricultural Organization of the United Nations, Rome 00100, Italy.

Fox, R. L., Olson, R. A. and Rhoades, H. F. (1964). Evaluating the sulphur status of soils by plant and soil tests .*Soil Sci. Soc. Amer .Proc.* **28** : 243-246.

Gerath, B., Berchmann, W. and Zajone, I. (1975). The effect of micronutrient, boron on yield development in winter rape. Boron in Agriculture. 116: 13.

Gomez, A. K. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. Intl. Rice Res. Inst., John Wily and Sons. New York, Chickester, Brisbane, Toronto, Singapore. P. 680.

Gupta, J. P., Wali, P., Gupta, S. C., Bedi, A. S., Khanna, Y. P. and Wali, P. (1996). Response of rapeseed-mustard to zinc, boron and sulphur. Annals of Agri Bio Research. Regional Agricultural Research Station, SKUAST, R.S. Pura, Jammu and Kashmir,India. **1** (1-2) : 25-28.

Gupta, T. R., Saini, J.S. and Gangasaran. (1985). Rai response to fertilizer. *Indian J. Agron.* **33** (3): 342-343.

Gupta, U. C. (1979). Boron nutrition of crops. *Adv. Agron.* **31**: 273-307.

Halder, N. K., Hossain, M. A., Siddiky, M. A., Rafiuddin, M and Ullah, M. H. (2007a). Performance of mustard varieties with boron fertilization in Calcareous Brown Floodplain Soil of Bangladesh. *J. Agron.* **6** (1): 171-174

Halder, N. K., Siddiky, M. .A., Nasreen, S., Sarkar, J. and Ullah, M. H. (2007b). Response of mustard as influenced by boron fertilization in Non-Calcareous Dark Grey Floodplain Soil at northern region of Bangladesh. *Asian J. Plant Sci.* **6** (2): 411-414

Haneklaus S., Paulsen H.M., Gupta A.K., Bloem E. and Schnug E. (1999). Influence of sulphur fertilization on yield and quality of oilseed rape and mustard. 10th Inter. Rapeseed Congress, Canberra, Australia, CD ROM.

Hidyatullah, M., Mudasir, H., Salroo, M.Y. and Bhat, G. N. (2004). Effect of sulphur and naphthalene acetic acid on growth, yield and bio-chemical parameters of Indian mustard (*Brassica juncea*). *Plant-Archives.* **4** (2): 423-425.

Hunt, J. (1980). Determination of total sulphur in small amount of plant material. Analyst.**105**: 83-85.

Hunter, A. H. (1984). Soil Fertility Analytical Services in Bangladesh. Consultancy Report. BARC. Dhaka.

Islam, M. R., Riasat, T. M. and Jahiruddin, M. (1997). Direct and residual effects of S, Zn and B on yield and nutrient uptake in a rice- mustard cropping system. *J. Indian Soc. Soil Sci.* **45**:126-129.

Islam, M. S. (1988). Micronutrient studies in soils and crops of Bangladesh. Paper presented at the meeting on "Policy Measures on Micronutrient Deficiency" held on April 21, 1988 at BARC, Dhaka.

Islam, M. S. and Anwar, M. N. (1994). Production technologies of oilseed crops. Recommendation and future plan. In proceedings of workshop on transfer of technology of CDP crops under Research Extension Linkage Programme, BARI, Gazipur. pp. 20 -27.

Islam, M. B. and Sarker, M. A. Z. (1993). Effect of different level of boron on the yield of mustard. Research Report 1992-93. OFRD, BARI, Rangpur.

Issa, P. and Sharma, S. N.(2006). Effect of levels and sources of sulphur on yield attributes, yield and quality of Indian mustard (*Brassica juncea*). *Indian J. Agron.* **51** (3): 217-220.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall Inc., Engle-wood, Cliffs, N.Y.

Jahangir, A. A., Afroz, R. S., Latif, A., Sarker, M. A. M. and Haq, S. M. I. (2005). Response of mustard to Mg and S fertilization. *Bangladesh J. Sci. Indus. Res.* **40** (1/2): 115-122.

Jahiruddin, M., Hoque, M. S., Hoque, A. K. M. M. and Roy, P. K. (1992). Influence of boron, copper and molybdenum on grain formation in wheat. *Crop Res.* **5** (1):35-42.

Jakson, J. F. and Chapman, K. S. M. (1975). The role of boron in plants. In Trace Elements in Soil-Plant-Animal Systems, (D.J.D. Nicholas and A. Esan. Ed.) Publ. London.

Jat, B. L. and Khangarot, S. S. (2003). Response of mustard {*Brassica juncea* (L) Czern and Coss} varieties to different levels of sulphur in loamy sand soil. *Agric. Sci. Digest.* **23** (2): 149-151.

Juel, O. (1980). Boron and Magnesium for oil seed rape, Boron Magnesium til rapes. *Dansk Frovl.* **62**(3): 51-52. [*Field Crop Abst.* **33** (1): 977, 1980]

Khanpara, V. D., Porwal, B. L., Sahu, M. P. and Patle, J. C. (1992). Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea*). *Indian J. Agron.* **38** (2): 266-269.

Koti, R.V., Panchal, Y. C. and Manjunath, S. (1989). Effect of sulphur on pod yield and oil content of mustard (*Brassica juncea*). *Soils Fert.* **53** (6):1024.

Krauze A. and Bowszys T. (2001). [Effect of the 'Star' spring oilseed rape sulphur fertilization date on the seed yield and contents of sulphur and fat]. *Rośliny Oleiste XXII,* 285-290 [in Polish].

Lewis, D. H. (1980). Boron, lignifications and the origin of vascular plants a unified hypothesis. *New phytol.* **84**: 209-229.

Malewar, G. U., Kate, S. D., Waikar, S. L. and Ismail, S. (2001). Interaction effects of zinc and boron on yield, nutrient uptake and quality of mustard. *J. Indian Soci. Soil Sci.* Marathwada Agricultural University, Parbhani, Maharashtra, India.**49** (4): 763-765.

Marschner, H. (1990). Mineral Nutrition of Higher Plants. Academic Press. London. P. 333

McGrath, S.P. and Zhao, F.J. (1996). Sulphur uptake, yield response and the interactions between nitrogen and sulfur in winter oilseed rape (*Brassica napus*). *J. Agric. Sci.* **126**: 53 - 62.

Mehdi, S, S., Singh, O.P. and Prahlad, S. (2006). Influence of sulfur fertilization on various quality characters of Indian mustard (*Brassica juncea* L.) in the north western tract of Uttar Pradesh. *Environment and Ecology.* **24** (Special 2): 338-340.

Mehrotra, O.N., Srivastava, R. D. L. and Mishra, P.H. (1977). Effect of micronutrients on the growth, yield and quality of Indian mustard. *Indian J. Agric. Chem.* **10** (1&2): 81-86.

Mengel, K. and Kirkby, E. A. (1987). Principles of Plant Nutrition. International Potash Institute, Switzerland.

Misra, S. K. (2003). Effect of sulphur and potassium on yield, nutrient uptake and quality characteristics of mustard (*Brassica juncea* L.) in Udic Haplustepts of Kanpur. *J. Indian Soci. Soil Sci.* **51** (4): 544-548.

Mohan, K. and Sharma, H. C. (1991). Effect of nitrogen and sulphur on growth, yield attributes, seed and oil yield of Indian mustard (*Brassica juncea*). *Indian J. Agron.* **37** (4): 748-754

Mondal, M. R. I. and Wahhab, M. A. (2001). Production technology of oil crops. Oil seed Res. Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Bangladesh. P. 4

Murphy, J. and Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim.* Acta. **27**: 31-36.

Naresh, K., Sandeep, S. and Vinay, S. (2006). Effect of iron and sulphur levels on yield, oil content and their uptake by Indian mustard (*Brassica juncea*). *Indian J. Agron.* **51** (1): 63-64.

Om, P. and Singh, B. P. (2002). Effect of sulphur fertilization on growth, yield and quality of Indian mustard *(Brassica juncea* L.) genotypes. *Annals Agric. Res.* **23** (2): 275-279.

Patel, J. R. and Shelke, V.B. (1999). Effect of farmyard manure, phosphorus and sulphur on yield attributes, yield, quality and net return of mustard. *Bhartya Krishi Anusandhan Patrika.* **14** (1-20): 93-99.

Piper, C. B. (1942). Soil and Plant Analysis Adellide Univ. Press, Australia.

Pradhan, A. C. and Sarkar, S. K. (1993). Growth and yield of rape-seed mustard varieties as influenced by sulphur and boron application. Indian-Agriculturist. BCKV, North Bengal Campus, Pundibari, Cooch-Behar, West Bengal, India. **37** (1): 21-26.

Rahman, A., Ali, M. I. and Jahiruddin, M. (1993). Response of two mustard varieties to added sulphur and boron in Old Brahmaputra Flood Plain Soil. *Bangladesh J. Nucl. Agric.* **9**: 25-28.

Rahman, M. L., Quddus, M. A. and Shae-Alam, M. (1978). Performance of two selected and two locally recommended varieties under different cultural conditions. Brassica Breeding Project. Department of Genetics plant Breeding, Bangladesh Agril. Univ. Mymensingh. Annul Report No. **2**(1977-78): 8-14.

Rajbir, S. (2005). Performance of Indian mustard (*Brassica juncea*) genotypes in relation to sulphur fertilization. Annals Agric. Res. **26** (3): 428-430.

Rajput, R. L., Yadav, R. P., Verma, O. P. (1993). Effect of sulphur levels and sources on mustard (*Brassica juncea)* production. *Bhartya Krishi Anusandhan Patrika.* **8** (3-4):185-188.

Ramesh, S., Dahiya, S. S., Yadav, H. D. and Mohinder, S. (2005). Effect of sulphur application on yield attributes, yield, S uptake and oil content of Indian mustard (*Brassica juncea* L.). *Haryana Agric. Univ. J. Res.* **35** (2): 135-138.

Saini, J. S., Dhaliwal, J. S. and Sharma, A. K. (1985). Effect of sulphur, zinc and boron in relation to nitrogen on the seed yield and oil content of Indian mustard. *Haryana J. Agron.* Punjab Agric. Univ., Ludhiana, India. **1** (1): 42-47.

Sakal, R., Singh, A. P., Sinha, R. B. and Bhogal, N. S. (1991). Relative susceptibility of some important varieties of sesamum and mustard to boron deficiency in calcareous soil. Fertiliser News. Rajendra Agricultural University, Pusa 848125, Bihar, India. **36** (3): 43-49.

Sandeep, S., Singh, T. P. and Singh, J. P. (2002). Effect of nitrogen and sulphur on the yield and oil content of Varuna mustard (*Brassica juncea* L.). *Progressive Agriculture*. **2** (2): 177.

Saran, G. and Giri, G. (1990). Influence of nitrogen, phosphorus and sulphur on mustard under semi-arid rainfed condition of North West. *Indian J. Agron*. **35** (1-2):131-126.

Sarkar, M. A. R., Sarker, A. U. Das, P. K. and Chowdhury, A. K. M. S. H. (1993). Effect of sulphur fertiliztion on the yield and yield components of mustard varieties. *Bangladesh J. Agril. Sci.* **20** (2): 351-358.

Schnug E., Haneklaus S. (1995). Sulphur deficiency in oilseed rape flowers – symptomatology, biochemistry and ecological impact. 9th Inter. Rapeseed Congress, Cambridge, 296-298.

Sen, R. and Farid, A. T. M. (2005). Effect of boron on the yield and yield components of mustard. *Bangladesh J. Agric. Environ*. **1** (1): 65-68.

Sharma, M.A.R., Sarker, A.U. and Chowdhury, A.K.M.S.H. (1992). Effect of sulphur fertilization on the yield and yield components of mustard varieties. *Bangladesh J. Agril. Sci.* **20** (2): 351-358.

Sharma, P.N. and Ramchandra, T. (1990). Water relations and photosynthesis in mustard plants selected to boron deficiency. *Indian J. Plant Physiol*. **33** (2): 150-154.

Sheppard, D. C. and Baten, T. E. (1980). Yield and chemical composition of rape seed in response to nitrogen, phosphorus and potassium. *Can. J. Soil Sci*.**60**: 153 - 163.

Shukla, M. P., Shanker, H. and Pathak, R. K. (1983). Sulphur, Zinc and Boron nutrition of rai. (*Brassica juncea*). *J. Indian Soc. Soil Sci.* **31** (4): 517-520.

Singh, B. and Kumar, V. (1994). Response of Indian mustard (*Brassica juncea*) to nitrogen and sulphur application under rainfed condition. *Indian J. Agron.* **41** (2):286-289.

Singh, B. P. and Singh, H. G. (1984). Comparative efficiency of sulphur on sulphur content at growth stages and uptake by mustard on vertisols. *Indian J. Agron.* **29** (2):179-184.

Singh, B. P., Prakash, O. M., Balwant, S. and Singh, S. K. (2002). Comparative performance of Indian mustard (*Brassica juncea*) genotypes in relation to sulphur fertilization. *Indian J. Agron.* **47** (4): 531-536.

Singh, D., Jain, .K. K. and Sharma, S. K. (2004). Quality and nutrient uptake in mustard as influenced by levels of nitrogen and sulphur. J. of Maharashtra Agricultural Universities. Department of Agronomy, College of Agriculture, Bikaner, India. **29** (1): 87-88.

Singh, K. S. and Bairathi, R. C. (1980). A study on the sulphur fertilization of mustard (*Brassica juncea* L. ezern and cross) in the semi arid tract of Rajsthan. *Ann. Arid Zone.* **19** (3):197-202.

Singh, O. (1984). The effect of sulphur fertilization at different stages of growth on C/N and S/N status of mustard (*Brassica campestris* c. var. sarson prain, cultivar type) plants. *Indian J. plant Physiol.* **27** (2):127-176.

Singh, V. K., Singh, V. and Singh, M. (1987). Response of Indian mustard (*Brassica juncea* L.) to sulphur fertilization. *Indian J. Agric. Sci.* **58** (10):754-756.

Singh,R. K. and Dhiman, M. (2004). Effect of sulphur fertilization in sustaining mustard productivity in rice-mustard cropping system. *Haryana J. Agron.* **20** (1/2): 7-9.

Sinha, P., Jain, R., Chatterjee, C., Sinha, P., Jain, R. and Chatterjee, C. (2000). Interactive effect of boron and zinc on growth and metabolism of mustard. Communications in Soil Science and Plant Analysis. Lucknow University, Lucknow, India.**31** (1-2): 41-49.

Sinha, R.B., Singh, A.P., Sakal, R. and Bhogal, N.S. (1991). Response of some field crops to boron application in calcareous soils. *J. Indian Soil Sci.* **39** (1): 118-122.

South Combe, J. E. (1926). Chemistry of oil industries (2nd edit). Constable and Company Ltd., London. P.144.

Sudhakar, P. C., Chandel, R. S. and Singh, K. (2002). Effect of sulphur, iron and silicon in the yield and growth of irrigated mustard. *Ann. Agric. Res.* **23** (3):483-485.

Suresh, K., Tripathi, P. N. and Room, S. (2002). Response of Indian mustard to sources and levels of sulphur in partially reclaimed salt affected soil. *Indian J. Agric. Sci.* **72** (1): 21-22.

Thomas, T. M. (1985). Oil seed rape production in Inland. In Advances in the production and utilization of cruciferous crops (edited by Sreson,H.). dordrecht, Netherlands. Martinus Nijhoff /Dr. W. Junk pub. Pp. 34-39. [*Field Crop Abst.* **40** (10): 768, 1987]

Tisdale, S. Z., Nelson, W.L. and Beaton, J. D. (1984). Soil Fertility and Fertilizers. Macmillan Pub. Co. N. Y.

Tomar, T. S., Singh, S., Kumar, S. and Tomar, S. (1997). Response of Indian mustard (*Brassica juncea)* to nitrogen, phosphorus and sulphur fertilization. *Indian J. Agron* **42** (1) : 285-288.

Trzcinski J. (2001). [Effect of selected agronomic practices on the health status of spring oilseed rape]. Praca doktorska, ATR Bydgoszcz, maszynopis [in Polish].

USDA. (1951). Soil survey manual by soil survey stuff. Bureau of plant industry, soil and agricultural engineering. Hand book no. 18, 205. US Govt. printing Office, Washington D.C.

Varma, S. C., Srivastava, R. K., Rajesh, S., Singh, S. K. and Bisen, P. K. (2002). Effect of varying levels of sulphur and potassium on yield and oil content of Indian mustard [*Brassica juncea* (L.) Czern & Coss.]. *Res. Crops.* **3** (3): 650-652.

Wielebski F., Wójtowicz M. (1993). Effect of increasing doses of sulphur on the seed yield and the content of glucosinolates in seeds of two double-improved oilseed rape cultivars. Post. Nauk Roln. 6, 63-67 [in Polish].

Yadav, O.P. and Manchandra, H.R. (1982). Effect of boron application in mustard (*Brassica campestris* L.) on a Sicrozem sandy soil. *J. Indian Soc. Soil Sci.* **30** (3): 408-410.

Yang,Y. A., Xu, H. K., Jie, Z. Q. and Wang, B. Y. (1989). Influence of B, N and K nutritional level on B uptake, quality and yield of rape seed. *Scientia Agricultura Sinica* **22** (1): 44-51. [*Field Crop Abst.* 43(5): 452, 1990]

Zhao, F. J., Witthers, P. J., Evans, E. J., Monaghan, J., Salmon, S. E., Shewry, P. R. and Mcgrath, S. P. (1997). Sulphur nutrition: An important factor for the quality of wheat and rapeseed. Soil Sci. Plant Nutr. **43**: 1137 - 1142.

APPENDICES

Appendix Table 1. Records of meteorological information (monthly) during the period from October, 2007 to February, 2008

Month	Air temperature (^{o}C)		Relative humidity		Rainfall (mm)
	Maximum	Minimum	Morning 6am (%)	Evening 6pm (%)	
October, 2007	31.57	24.33	93.83	77.67	12.12
November, 2007	29.52	18.99	95.26	74.76	2.30
December, 2007	25.91	13.55	93.38	72.38	-
January, 2008	24.38	13.32	94.70	72.90	2.54
February, 2008	24.63	13.79	88.16	62.55	3.06

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Library

Summary of analysis of variance of growth character of mustard

Appendix Table 2. Summary of analysis of variance of yield and yield attributes of mustard as influenced by different level of sulphur and boron

Sources of variation	Degrees of freedom	Mean square (MS)				
		Plant height(cm)	No. of siliqua plant^{-1}	Primary branch plant^{-1}	No. of Seeds siliqua^{-1}	Length of siliqua
Replication	2	18.08	13.716	0.036	7.72	0.193
Sulphur	3	561.23*	3198.7*	3.95*	100.47*	6.08*
Boron	3	198.84*	4025.47*	2.86*	83.79*	0.056*
Sulphur × Boron	9	59.97*	528.22*	0.216*	13.79*	0.424*
Error	30	52.77	533.33	0.228	4.98	0.456

* Significant at 5% level of probability

Appendix Table 3. Summary of analysis of variance of yield and yield attributes of mustard as influenced by different level of sulphur and boron

Sources of variation	Degrees of freedom	Mean square (MS)				
		1000 seed weight(g)	Seed Yield (t ha^{-1})	Stover Yield (t ha^{-1})	Oil content (%)	Protein content (%)
Replication	2	0.016	0.076	0.979	0.189	0.062
Sulphur	3	0.236NS	0.841*	1.576*	1.062*	27.58**
Boron	3	0.049NS	0.318*	1.115*	0.724*	42.06**
Sulphur × Boron	9	0.022NS	0.147*	0.245*	0.094*	04.29**
Error	30	0.029	0.092	0.169	0.103	0.084

* Significant at 5% level of probability

** Significant at 1% level of probability

NS= Non significant.

26 (06) Soil S.
07/10/09

Field view of the experiment

Sher-e-Bangla Agricultural University
Library
Accession No. 37623
Sign: Date: 13/02/14

Appendix Figure 1. Field view of experimental plot at 20 DAS.

Appendix Figure 2. Field view of experimental plot at 50 DAS.

Library

Appendix Figure 3. Field view of experimental plot at 80 DAS.