Department of Agronomy and Agricultural Extension PhD Thesis

2015

Effect of Sulpher, Boron and Irrigation on Growth, Yield and Quality of Mustard

Yeasmin, Farida

University of Rajshahi

EFFECT OF SULPHER, BORON AND IRRIGATION ON GROWTH, YIELD AND QUALITY OF MUSTARD

PH. D. THESIS

BY
FARIDA YEASMIN

December, 2015

AGRONOMY FIELD LABORATORY
DEPARTMENT OF AGRONOMY
AND AGRICULTURAL EXTENSION
FACULTY OF AGRICULTURE
UNIVERSITY OF RAJSHAHI
RAJSHAHI-6205, BANGLADESH

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DECLARATION

I do hereby declare that the whole of the work now submitted as a thesis entitled "**EFFECT OF SULPHER, BORON AND IRRIGATION ON GROWTH, YIELD AND QUALITY OF MUSTARD"** for the degree of Doctor of Philosophy is the results of the investigation as embodied here are original and have not been submitted else where for any other degree.

Date:

____
(Farida Yeasmin)
Candidate


Dedicated
To
My Respected Mother And
Affectionate Daughter

CERTIFICATE

I hereby certify that the research work entitled **"EFFECT OF SULPHER, BORON AND IRRIGATION ON GROWTH, YIELD AND QUALITY OF MUSTARD"** submitted for the degree of Doctor of Philosophy in the subject of Agronomy is a bonafide research work carried out by **FARIDA YEASMIN** under my supervision in the University of Rajshahi, Rajshahi-6205, Bangladesh. The results of the investigation, which embodied here are original and have not been submitted before in substance for any other degree of this or any other university.

(Dr. Md. Belal Hossain)
Associate Professor & Supervisor
Department of Agronomy and
Agricultural Extension
University of Rajshahi
Rajshahi-6205
Bangladesh.

(Professor Dr. Md. Arifur Rahman)
Co-supervisor
Department of Agronomy and
Agricultural Extension
University of Rajshahi
Rajshahi-6205
Bangladesh.

ACKNOWLEDGEMENT

''Alhamdulillah" at first the author would like to show my gratitude and thanks to the all mighty Allah who has been with me all the way and given me the scope to study on the earth.

The author expresses her deep sense of gratitude, heartfelt respect, profound appreciation and indebtedness to her Research Supervisor Associate Professor Dr. Md. Belal Hossain, Department of Agronomy and Agricultural Extension, Faculty of Agriculture, University of Rajshahi for his constant encouragement, constructive and scholastic guidance, whole hearted assistance and valuable instructions in carrying out the research work.

The author is profoundly indebted and sincerely grateful to her Research Co-supervisor Dr. Md. Arifur Rahman, Professor, Department of Agronomy and Agricultural Extension, Faculty of Agriculture, University of Rajshahi, Rajshahi-6205, Bangladesh for his scholastic guidance, constant inspiration, immense encouragement, cordial behavior and invaluable suggestions and timely support throughout the entire period of this research as well as preparing this dissertation.

Profound appreciation and gratefulness are intended to the Chairman and all the respected teachers of Department of Agronomy and Agricultural Extension, Faculty of Agriculture, University of Rajshahi, Rajshahi-6205, Bangladesh for their suggestions and encouragement during the whole course of work.

The author thankfully acknowledges my gratitude to my respectable teachers Professor Dr. Mohammad Amirul Islam, Department of Biochemistry and Molecular Biology, University of Rajshahi and professor Dr. M. Matiar Rahaman, Department of Biochemistry and Molecular Biology, University of Rajshahi.

The author offers with undulated emotion, her supreme gratitude and deepest sense of respect to her beloved parents Md. Fayzul Haque and Most. Sufia Haque, elder brother Engr. Md. Shafiqul Islam and younger brothers Dr. Md. Shariful Islam, Dr. Saifullah Mansur and Md. Shahidullah Mansur and younger sister (Sharifa Yeasmin) for their relentless efforts, affectionate feelings, great sacrifices, blessing cooperation in all phases of her academic pursuit. Thanks are also extended her sister in-laws, Sumaiya sultana and Dr. Iffat disha. The author wants to say thanks to her Father in-law, S.M. Khalilur Rahman and Mother in-law, Most. Jahanara Begum.

The author wants to say thanks, to my classmates and friends, for their active encouragement and inspiration; personal acknowledgements are made to Sadia Abedin.

Thanks are also extended to all staff members and laboratory staffs, Department of Agronomy and Agricultural Extension, Faculty of Agriculture, University of Rajshahi, Rajshahi-6205, Bangladesh.

The author would like to express her cheerful acknowledgements to the sweet of well wisher specially Khadiba Khima, Shirin Jahan, Sabiha Sultana, Milon, Tamanna, Rashed, Asad, sohan and Adil for their kind cooperation through the whole research period.

The author expresses her special thanks to her lovely daughter Zaihan for her sacrifice during the study period.

The author wish to extend special thanks to my husband S. M. Zahidur Rahman for his constant encouragement and continuous support in various ways during the whole period of study.

The author expresses her heartfelt gratitude to Mr. Abu Daud and Mustofa to co-operate for collecting data and other activities. Thanks are also extended to Md. Anwar Arif, Md. Modhu and Rafshan for their careful composing of thesis.

The Author

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Argo-ecological zone
BAU	=	Bangladesh Agriculture University
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
BADC	=	Bangladesh Agricultural Development Corporation
CV	=	Cultivar
CGR	=	Crop Growth Rate
Cm	=	centimeter
DAS	=	Days after sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
gm^{-2}	=	Gram Per Meter Square
$gm^{-2}day^{-1}$	=	Gram Per Meter Square Per Day
ha	=	Hectare
i.e.	=	That is
LAI	=	Leaf Area Index
LS	=	Level of Significance
Kg	=	Kilogram
ha^{-1}	=	Per Hectare
m	=	Meter

m^2	=	Square Meter
mm	=	Millimeter
L.	=	Linneaus (Carolus Linneaus)
LS	=	Level of significant
NAR	=	Net Assimilation Rate
NS	=	Not Significant
OFRD	=	On Farm Research Division of BARI
ppm	=	Parts Per Million
pH	=	Negative logarithm of hydrogen ion (H^+) concentration
t	=	Ton
TDM	=	Total Dry Matter
Viz	=	Namely
%	=	Percent

ABSTRACT

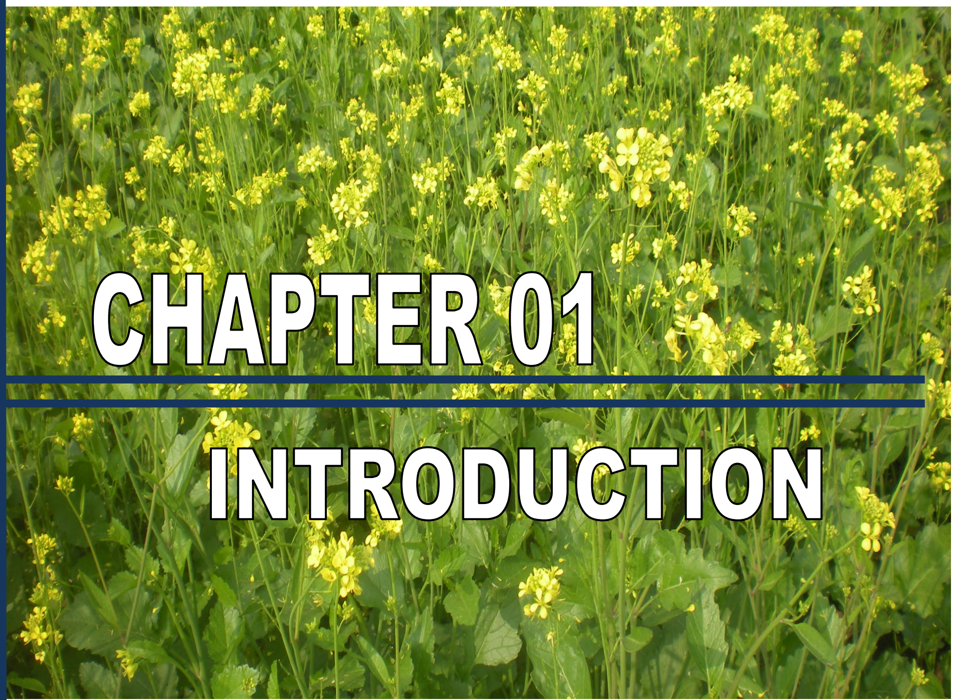
The study was carried out at the Agronomy field laboratory, University of Rajshahi, Bangladesh during the period of 2012-2013 and 2013-2014 to study the effect of irrigation, sulpher and boron on growth, yield and quality of mustard. The treatment comprised three levels irrigation (control, one and two), four levels sulpher (0, 30, 40, 50 kg S ha^{-1}) and four levels boron (0, 0.5, 1.5, 2 kg B ha^{-1}). The experiment was layout in split-split plot design with three replications by assigning irrigations in main plots, sulpher in sub plots and boron in sub-sub plots.

Phenological characters differed significantly due to irrigation, sulpher and boron at different growth stages. The irrigated field produced the highest plant height (cm) and maximum number of leaves than non irrigated field. The highest plant characters were observed when field was fertilized with 40 kg S ha^{-1} and 1.5 kg B ha^{-1}. The highest growth parameters like TDM, CGR, LAI and NAR were observed in irrigated field where applied different levels of sulpher and boron. The lowest values were found in control. Result showed that TDM and LAI increased with the advancement of plant ages.

Results showed that yield and yield contributing characters i.e. number of branches, number of siliqua $plant^{-1}$, siliqua length (cm), number of seeds $siliqua^{-1}$, number of normal seeds $siliqua^{-1}$, number of deformed seeds $siliqua^{-1}$, 1000- seed weight (g), seed yield (t ha^{-1}) and straw yield (t ha^{-1}) were significantly influenced due to irrigation, sulpher and boron levels in both the years. The highest yield contributing characters were found

when one irrigation was given which was statistically similar to two irrigations. When the field was fertilized with sulpher and boron, the yield components were found in maximum. The yield was highest when one irrigation, 40 kg S ha^{-1} and 1.5 kg B ha^{-1} were applied to the field which was statistically similar to other doses. Seed yield positively correlated with number of branches, number of siliqua $plant^{-1}$, siliqua length (cm), number of seeds $siliqua^{-1}$, number of normal seeds $siliqua^{-1}$, 1000-seed weight (g). Irrigated and fertilized plants gave significantly higher quality of mustard.

From the results it may be concluded that, application of one irrigation at flowering stage with 40 kg S ha^{-1} and 1.5 kg B ha^{-1} are better for maximizing growth, yield and quality of mustard.

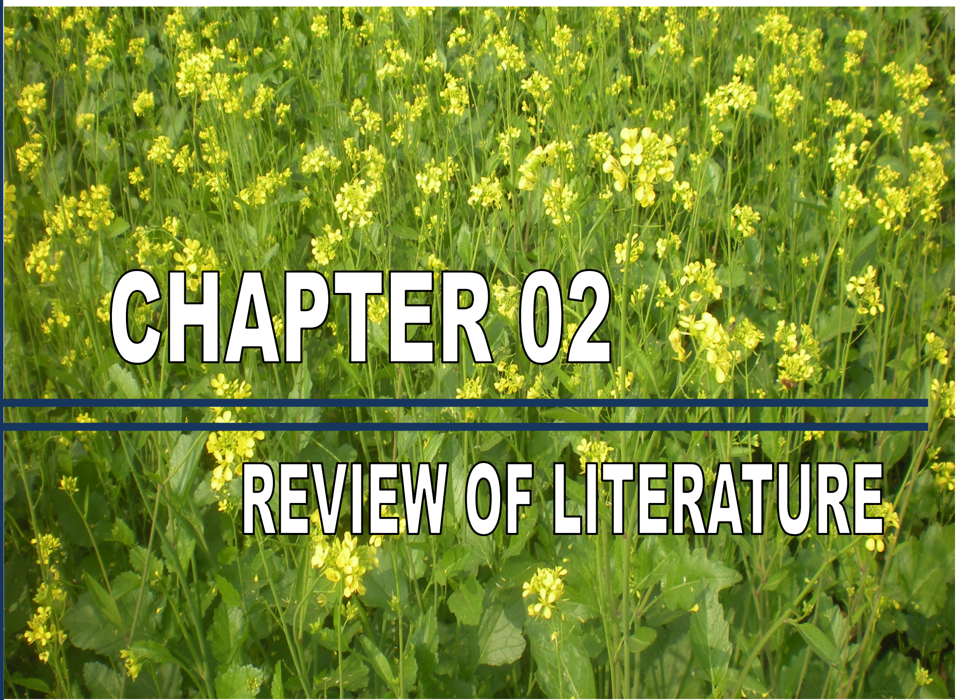


CHAPTER 01

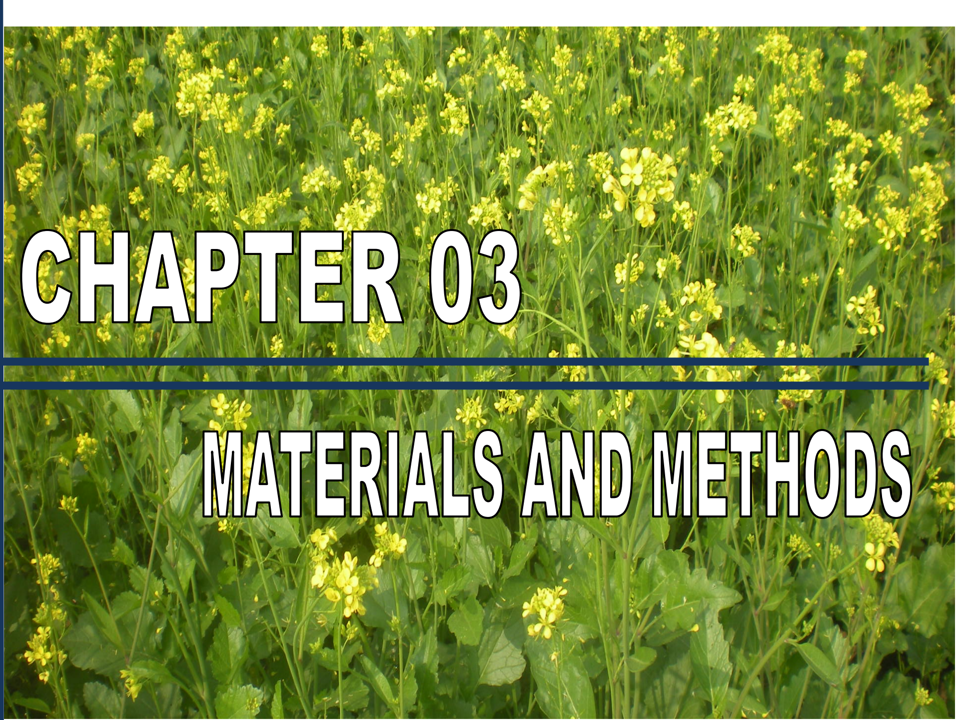
INTRODUCTION

CHAPTER 02

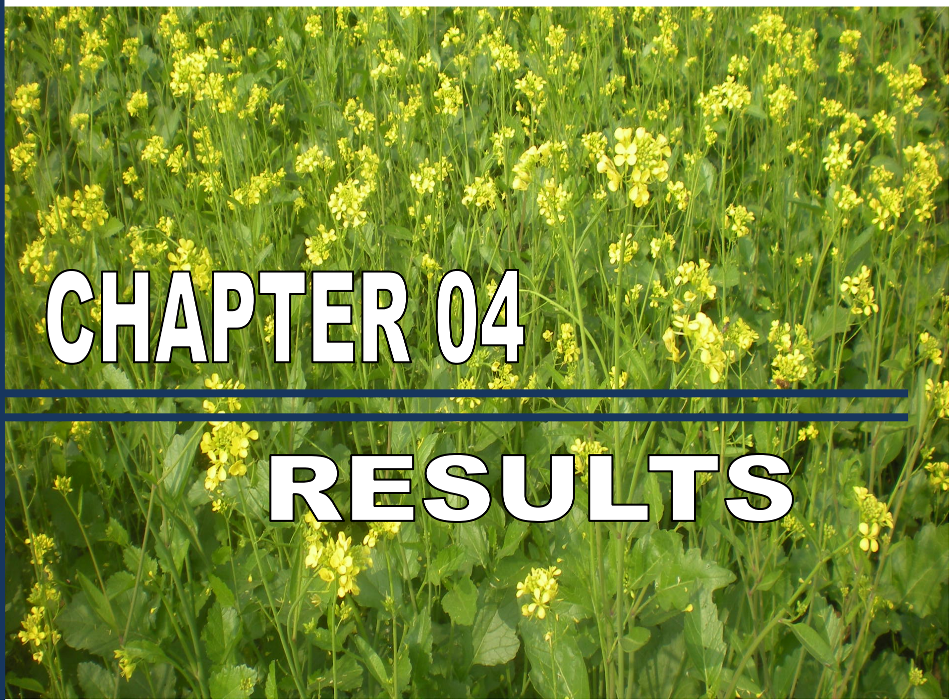
REVIEW OF LITERATURE



CHAPTER 03



MATERIALS AND METHODS



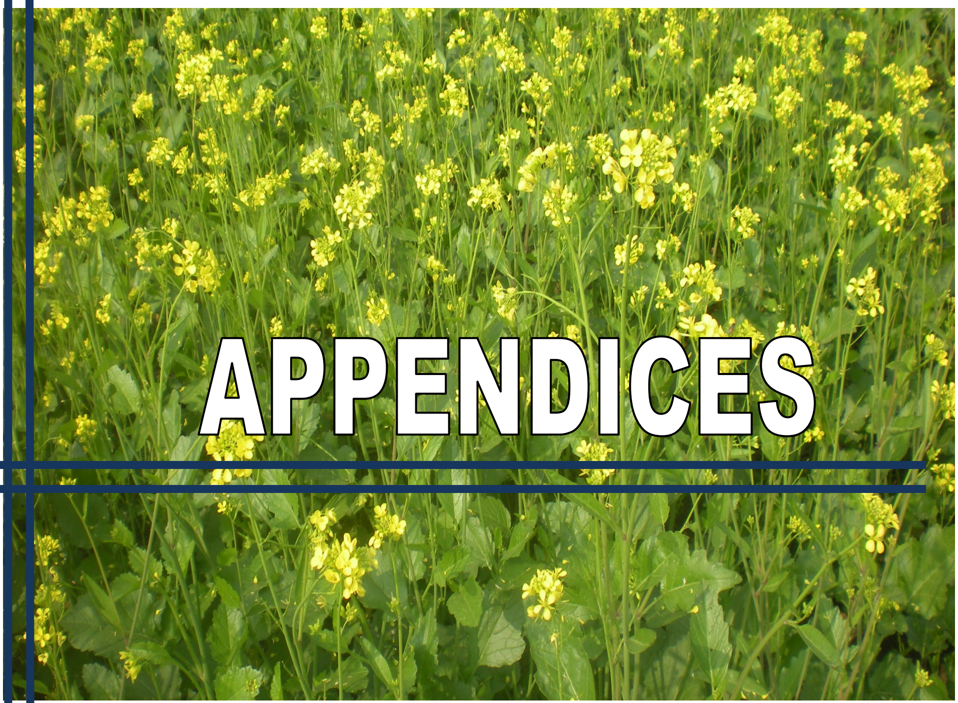
CHAPTER 04

RESULTS

CHAPTER 05

DISCUSSIONS

REFERENCES



APPENDICES

Chapter 1

INTRODUCTION

Oil seed crops are the most important commercial crop in Bangladesh. Edible oils are next to food grain in Bangladesh diet. The crops that is cultivated for production of oils. The rapeseed and mustard, sesame, Sunflower, safflower, linseed, soybean, niger, groundnut and castor are most important oil seed crops of Bangladesh. *Brassica* oilseed plays an important role as a fat substitute in our daily diet. It is one of the major oilseed crops of Bangladesh that covers 66.22% of total oilseed area (BBS, 2011). The present area and production of mustard are 2.42 lac hac, 2.22 lac m ton and the average yield is 0.9 t ha^{-1} (BBS, 2011). Its production is 3.34 lac metric tons against a total oilseed production of 5.48 lac metric tons annually and it acreages is 3.52 lac hectares against a total oil seed area of 5.32 lac hectares (Krishi Dairy, 2008). At present, the local production of edible oil meets only 25% of the country requirement (Chowdhury and Uddin, 1990). In this country, the average yield of mustard is only 0.74 t ha^{-1} compared to about 2.77 t ha^{-1} in the European countries (FAO, 2001). The average yield of oil crops in Iran is 245000 t (Area harvested 521000 ha), whereas the world average yield of oil crops is 261,099,000 t (Area harvested 157,382,000 ha) (FAO, 2010). It has a remarkable demand for edible oil in Bangladesh. Rapeseed is the major oilseed crop in Bangladesh covering about 70 % of the total production. The area and production of mustard of our country was about 0.481 million hectares and 0.536 million tons, respectively with an average yield of 1.11 t ha^{-1} during 2010-2011 (AIS, 2012). In Bangladesh, many types of oilseed crops are grown, which are occupied 5.03lac hectare of land with 4.99lac metric tons of production (DAE, 2009). Mustard plant belongs to the genus *Brassica* under the family cruciferae. Edible oil of mustard plays important role in human nutrition. As high energy components of food, edible oils are important for meeting the calorie requirements. This oil is widely used in cooking and as medical ingredients. Moreover, mustard oil cake is used as feed for cattle, fish and also as good manure. It considered as the staple food in many countries of the World. In Bangladesh, it is considered as a vegetable crop.

The competition of mustard with other food grains has shifted the cultivation of mustard to marginal lands causing poor productivity. Edible oil requirement is increasing day by day due to higher population growth rate. Bangladesh has been facing acute shortage of edible oil for the last several decades. Our internal production can meet only about 21% of our consumption. The rest 79% is met from the import. To meet up the growing demand of oilseed, it is urgent to ensure its higher production. It is almost impossible to increase the production by increasing area because of crop competitions. Therefore, production per unit area can be increased by adopting improved technology and inputs. In order to increase the production of mustard, emphasis should be given to calculate high yielding varieties applying different modern management practices with special consideration of irrigation. There is a wide scope for increasing production of mustard, if proper irrigation and other irrigation inputs are made (Mandal *et al.* 2006).

Mustard is responsive to irrigation, and the most efficient water use by mustard depends on number of irrigation as well as timing of irrigation at critical growth stages. Increase in the amount of water by increasing the number of irrigation augmented the leaf water potential, stomatal conductance, light absorption, and leaf area index which ultimately increased growth, yield attributes (Ray *et al.* 2014) and quality (Majid and Simpson 2002). There are several experimental evidence that mustard crop essentially require a range of water from 60 to 169 mm throughout its life cycle (Rahman *et al*. 1984). Irrigation has been found to increase seed yield, 1000-seed weight, number of siliqua plant, and number of seed plant of this crop. Irrigation has also an effect on mustard to increase nitrogen uptake along with other nutrients (Reddy *et al.* 1989) resulting in improved yield and yield attributes.

Bangladesh receives high average annual rainfall (1500-2200 mm), but 80% of it occurs within the rainy season (June- September) leaving the winter season (November-February). Due to shortage of soil moisture, many areas remain fallow during the winter period. In some areas, mustard is cultivated without irrigation. Several studies in the past have indicated the irrigation need of mustard.

Mustard is responsive to sulpher in comparison to other crops. *Oleiferous Brassica* crops in general have high sulpher requirement owing to higher seed and oil yield. Sulpher is the key components of balanced nutrient application for higher yields and superior quality production. In general, about 97% soils of Bangladesh are deficient in sulpher and this deficiency is becoming acute day to day due extensive use of sulpher free fertilizers and intensive crop production. So to increase total production, increased yield per unit area of land is must in Bangladesh. This increase can be achieved by using improved varieties and adopting improved management practices in the field levels (Mondal and Wahhab, 2001). However, no data are available about the effect of sulpher on the physiological aspects of rapeseed as well as biological and economic yields. Therefore, there is a good scope to work on the morphological and yield aspects of mustard, especially with sulpher fertilizer. Sulphur increased dry matter in plant and thus it is effective on growth analyses. Growth analysis is the procedure of analyzing plant growth rate by expressing it as the algebraic product of a series of factors. Plant growth analysis is generally expressed in the indices of growth, such as crop growth rate, relative growth rate, net assimilation rate, leaf area index, and leaf area ratio. Mandal and Sinha (2004) reported that dry matter production and CGR significantly increased with increasing level of sulphur up to 20 kg S. ha^{-1} and LAI up to 40 kg S.

Application of sulphur was reported to increase yield and yield attributes of mustard (Patel *et al.* 2009, Kumar *et al.* 2011), which also has a significant effect on oil, fatty acid (Ahmad and Abdin 2000) and glucosinolates content in mustard seed (Falk *et al.* 2007). The relative proportions of individual glucosinolates viz. sinigrin (allyl isothio-cyanate), gluconapin (3-butenyl glucosinolate) and progoitrin (2-hydroxy-3-butenyl glucosinolate) are influenced by sulphur application (Hassan *et al*. 2007). Consequently, the present study was based on the hypothesis that increasing irrigation and sulphur levels may enhance the yield attributes, yield, sulphur uptake and quality of mustard.

Sulphur (S) deficiency in *Brassica* **c**rops is increasing worldwide due to the use of high-grade sulphur fertilizer, the breeding of high yield crop varieties, the declining use of elemental S for plant purposes and but not least the efficient reduction of atmospheric S depositions in industrial area. Sulphur is a macronutrient, required for plant growth as in the same order as that of Phosphorus (Zhao *et al.* 1997). Mustard and oil seed rape are highly susceptible to S shortage and respond well to S fertilization (McGrath and Zhao, 1996; Zhao *et al.* 1997). Sulphur fertilizers have been reported to increase the seed yield and oil content of mustard (Varmani and Gulati, 1971 and Singh *et al*. 1988). Further the S nutrition of a crop often has a strong influence on the quality of the product, because of its essential role in the synthesis of amino acids (e.g. cystine, cysteine and methionine), coenzymes (e.g. biotin, coenzyme A, thiamine pyrophosphate and lipoic acid) and some secondary metabolites. Sulphur is responsible for characteristic taste and smell of mustard (Tisdale *et al.* 1984). On the other hand, an excessive S supply can lower the quality of mustard meal as animal feed by increasing the glucosinolate concentration.

Farmers generally apply lower amount of NPK and they did not use boron fertilizer in mustard. But, Singh (1963) reported that boron increases the number of siliqua and yield of mustard. The seed yield of mustard plants is greatly influenced by boron particularly where soil is deficient in boron. *Brassica* group generally has a high boron requirement (Mengel and Kirkby, 1987). Mustard is sensitive to low B supply and severe deficiency may result in floral abortion and significant drop in seed production (Yang *et al*. 1989). Therefore, a comprehensive study is needed to find out the effect of boron on rapeseed for extension and farmer's recommendation. It is suspected that this variety is sensitive to boron deficiency (Zaman *et al.* 1998). It is therefore, necessary to identify optimum dose of sulphur and boron for obtaining higher yield of rapeseed.

Dubey and Khan (1991) reported that sulphur upto 30 kg ha^{-1} significantly increased seed yield of mustard.

The essentiality of B for higher plants was first established by K. Warington in 1923 (Warington, 1923). Recent advances in B research have greatly improved an understanding for B uptake and transport processes (Brown *et al.* 2002, Frommer, Takano *et al.* 2002), and roles of B in cell wall formation (Matoh, 1997, O'Neill *et al.* 2004), cellular membrane functions (Goldbach *et al.* 2001), and anti-oxidative defense systems (Cakmak and Romheld, 1997). Boron deficiency is a worldwide problem for field crop production where significant crop losses occur both in yield and quality (Bell *et al.* 1990; Nyomora *et al.* 1997; Wei *et al.* 1998). Availability of B to plants is affected by a variety of soil factors including soil pH, texture, moisture, temperature, oxide content, carbonate content, organic matter content and clay mineralogy (Goldberg *et al.* 2000). Zajonc *et al. (*1985) observed that B had positive effect on the formation of large pods with 25-26 seeds pod^{-1}.

Boron is generally less available in clay soils and availability increases with increasing temperature (Fleming, 1980). Soil pH is regarded as a major factor regulating B availability in soils. Increasing pH favours its retention by soils or soil constituents (Mezuman and Karen, 1981; Bloesch *et al.* 1987; Goldberg. 1997). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Dear and Lipsett. 1987, Noppakoonwong *et al.* 1997).

Thus, B fertilization is necessary for improvement of crop yield as well as nutritional quality. There are numerous reports on the positive response of mustard to B fertilization (Islam, 2005; Hossain *et al.* 1995 and Saha *et al.* 2003). Considering the facts above, the present study was undertaken to find out the optimum rate of B application for achieving the highest yield potential of mustard in this soil and to see the nutrient uptake pattern due to variation of rate of B application.

Considering the entire above scenario, the present study was undertaken with the following objectives:

1. To observe the effect different levels irrigation on growth, yield and quality of mustard.
2. To evaluate the effect of different levels of sulphur on growth, yield and quality of mustard.
3. To find out the effect of different levels of boron on growth, yield and quality of mustard.
4. To investigate the interaction effect between irrigation and sulpher on growth, yield and quality of mustard.
5. To find out the interaction effect of irrigation and boron on growth yield and quality mustard.
6. To study the interaction effect of sulphur and boron levels, if there any, for better growth, yield and quality of mustard.

Chapter 2

REVIEW OF LITERATURE

Mustard (*Brassica* spp. L) is one of the most important oil seed crop in Bangladesh but very few experimental evidences are available regarding the response of irrigation, sulpher and boron fertilizer on this crop. Some of the works pertinent to the present study have been reviewed below:

2.1. Effect of irrigation on mustard

Raza *et al.* (2015) to study the performance of Canola (*Brassica napus* L.) and Camelina (*Camelina sativa* L.) under different irrigation levels, a field experiment was conducted on 20th of November 2013. In experiment, growth and yield of two crops (V_1= Canola and V_2= Camelina) were compared under four different irrigation levels (To= Control, T_1= 3 irrigations, T_2= 2 irrigations, T_3= 1 irrigation). The growth parameters (Plant population, Plant height , Leaf area index, Root fresh and dry weight), yield parameters (seed yield, number of pods per plant, number of seeds per pod, pod length, biological yield and harvest index) and quality parameters (Protein contents and Oil contents) were recorded using standard procedures.

Ray *et al.* (2015) conducted field experiments on clay loam soil during winter season of 2010–2011 and 2011–2012 at the Research Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to study the influence of sulphur (S) levels and irrigation on quality and yield of mustard (cv. Varuna, T-59). Double irrigation at flower initiation (30 days after sowing (DAS)) and siliqua development stages (60

DAS) was best with respect to growth, yield attributes, yield, S uptake and oil percent in seed.

Verma *et al.* (2014) conducted a field experiment during the *Rabi* season of 2008-09 at Agronomy Research Farm, N.D.U.A and T., Kumarganj, Faizabad, to evaluate the response of new released Indian mustard (*Brassica juncea* L.) varieties to irrigation for better growth, yield of mustard crop. Treatments consisted of four irrigation schedule I_1 (no irrigation), I_2 (one irrigation at branching), I_3 (one irrigation at siliqua formation) and I_4 (two irrigation at branching + siliqua formation) and three varieties (NDYR-8, Maya and NDR-8501). All the growth and yield attributes and yield parameters were increased significantly with I_2 treatment (irrigations at branching + siliqua formation) which was significantly superior over rest of treatments.

Singh *et al.* (2014) a field experiment was conducted at Agronomy Research Farm, ND University of Agriculture & Technology, Faizabad, UP during the Rabi season of 2009-10 and 2010-11 to assess the influence of different dates of sowing and irrigation scheduling on growth and yield of mustard (*Brassica juncea* L). Plant height (cm), leaf area index and dry matter accumulation (g plant^{-1}) and yield attributes like number of siliqua plant^{-1}, number of seeds siliqua^{-1}, length of siliqua (cm) and seed and stover yields of mustard crop were significantly higher with irrigation at 0.7 IW/CPE ratio.

Sahay *et al.* (2013) four cultivars namely, *B.campestris* cv. P. Gold, *B. juncea* cv. P. Bold, *B. napus* cv. GSL-1 and *B. nigra* cv. IC-247 selected on the basis of their tolerance/susceptibility, were grown under urban wastewater of Aligarh to study their performance evaluated on the basis of growth, yield, quality and physiological traits and compared to ground water. The NPK was applied as uniform dose at the rate of 80 kg N ha^{-1}, 30 kg P $^{-1}$ha and 30 kg K ha^{-1} respectively. The result demonstrated that four cultivars of *Brassica* receiving wastewater as a source of irrigation were differing significantly for various parameters studied. Moreover wastewater irrigation resulted in increased of length, fresh weight, dry weight of shoot and root, leaf area, chlorophyll content and leaf nitrogen, phosphorus and potassium content. The oil content and oil yield most important parameters was significantly increased in wastewater irrigated *Brassica* cultivars.

Hossain *et al.* (2013) carried out the experiment at Agronomy Field laboratory, Department of Agronomy and Agricultural Extension, university of Rajshahi, to study the effect of irrigation and sowing method on yield and yield attributes of mustard. The experiment consists of two factors i) irrigation viz. no irrigation (I_0), one irrigation (I_1)and two irrigations (I_2) ii) sowing method viz. line sowing method (M_1) and broadcasting method (M_2). The highest plant height, number of branches plant^{-1}, filled siliqua plant^{-1}, sliqua length, number of seed siliqua^{-1}, 1000-seed weight and stover yield were obtained from I_2 (two irrigations) and consequently it produced the highest seed yield.

Piri *et al.* (2013) conducted a field experiment at Indian Agricultural Research Institute, New Delhi during the crop season of 2007 to 2008 and 2008 to 2009 to study the effect of irrigation and sulphur on yield and water use efficiency of Indian mustard *(Brassica juncea* var. Pusa Jagannath). The treatments consisted of three levels of irrigation in the main plots [no irrigation, one irrigation at 45 days after sowing (DAS), and two irrigations at 45 DAS and 90 DAS] and four levels of sulphur in sub-plots (0, 15, 30, and 45 kg S ha^{-1}). The results showed that in both years of experimentation, application of two irrigations significantly increased the India mustard yield as indicated by dry matter accumulation, seed production, biological yield, and harvest index, in comparison to no irrigation. Also, the application of one irrigation, significantly enhanced seed and biological yield and the highest harvest index was obtained from the application of two irrigations in both years of the study.

Piri (2012) conducted to Study of yield and yield components of black mustard (*Brassica nigra*) in condition of sulphur fertilizer application and water stress, a field experiment was conducted at research farm of Payame Noor University of Zahedan during crop season of 2010-11. The treatments consisted of three levels of irrigation: no irrigation, one irrigation at 45 days after sowing (DAS) and two irrigations at 45 DAS and 90 DAS, in main plots and four levels of sulphur: 0, 15, 30 and 45 kg S ha^{-1}, in sub-plots. The results showed that application of two irrigations than one and no irrigation significantly enhanced seed and biological yield, and harvest index.

Rafei *et al.* (2011) carried out the effect of four irrigation regimes (I_1-Irrigation after 70 mm, I_2-Irrigation after 100 mm, I_3-Irrigation after 130 mm and I_4-Irrigation after 160 mm evaporation from class A pan) and two dates of sowing (August 30 and January 27) were studied during growing season of 2009-2010 at I.A. University of Takestan, Iran. Among the irrigation treatments, irrigation after 70 mm evaporation from class. A pan, gave significantly highest plant height, seed $siliqua^{-1}$, siliqua $plant^{-1}$, thousand seed weight and seed yield. The highest seed yield of 3034 kg ha^{-1} was obtained.

Abraham *et al.* (2010) conducted a field experiment with four irrigation levels [No irrigation= (I_0), irrigation at pre-flowering (I_1), at pod formation (I_2), at both pre-flowering and pod formation (I_3)]. Irrigation on an average increased the mustard yield by 6.47% (I_1), 12.18% (I_2), and 13.18% (I_3) compared to no irrigation (I_0).

Satyavan *et al.* (2009) reported that irrigation with saline water (11.63 dS m^{-1}) resulted in 15% yield compared reduction to canal water (non- saline treatment. They also reported that the minimum salt accumulation was observed in upper soil layer (0-30cm) when irrigated with EC_{iw} of 11.63 dS m^{-1}. They further noted that the interactive effects between the irrigation levels and quality of irrigation water were found to be non significant.

Sultana *et al.* (2009) carried out the study at the Agronomy Field of Sher-e- Bangia Agricultural University farm, Dhaka, Bangladesh during November 2006 to March 2007 to evaluate the effect of irrigation and variety on growth, yield attributes and yield of rapeseed. The treatment comprised of three levels of irrigation viz. no irrigation, one irrigation at 20 DAS, one irrigation at 35 DAS, two irrigations at 20 and 35 DAS and three irrigations at 20, 35 50 DAS. Three irrigations (at 20, 35 and 50 DAS) increased economic yield with higher values of harvest index as the yield attributes like branches $plant^{-1}$, siliqua $plant^{-1}$, seeds $siliqua^{-1}$ and 1000 seed weigh were higher. The seed yield with three irrigations was 111.93% and 10.73% higher than no irrigation and two irrigations, respectively.

Austrilian Agronomy Conference 2008, reported that a field experiment was carried out during the rabi seasons of 2003-2004 and 2004-2005 at I.A.R.I.(Indian Agriculture Research Institute), New Delhi

(India) to examine the effect of irrigation and sulphur on yield attributes, yield, quality and water use efficiency of Indian mustard (*Brassica juncea*). Results indicated that two irrigations at 45 days after sowing (DAS) and 90 DAS recorded significantly higher number of siliqua per plant, increased 1000 grain weight, seed yield, oil yield and protein content over one irrigation treatment and the control. However for number of seeds per siliqua and oil content, one irrigation at 45 DAS remained parallel with two irrigations. The water use efficiency was highest with one irrigation at 45 DAS.

Vyas *et al.* (2007) conducted an experiment for five consecutive rabi seasons of 1997-98 to 2001-2002 at the Anand Agricultural University, Anand, Gujarat, India. They reported that there was no significant difference in seed yield due to cultivars (Varuna and GM-2). They also reported that three irrigations produced significantly higher mustard seed yield over the no irrigation treatments. They noted that the flowering and pod development phases of mustard were the most sensitive to weather parameters. They further noted that temperature range explained the highest variation in the mustard seed yield.

Piri and Sharma (2007) reported that without irrigation, the seed yield of Indian mustard increased from 0 to 45 kg ha^{-1}, whereas with 1 to 2 irrigation. The seed yield increased with 30 kg S ha^{-1}.

Fodor (2007) conducted an experiment to determine the effect of irrigation on the characteristics and seed yields of white mustard cultivars (Viscount, Veronika, Ceska Zlata, Tinney, Budakalaszi sarga and LM-1). He reported that seed yield and 1000 seed weight increased by irrigation in each of the cultivars.

Rajput *et al.* (2006) reported that the highest seed yields were obtained with sowing on 10-17 October, and irrigation at pre-flowering stage or at pre-flowering + siliqua development stages. They reported that the total yield was highest with irrigation at pre-flowering + siliqua development stages.

Piri and Sharma (2006) reported that seed yield of mustard increased significantly with increasing levels of irrigation significantly increased the plant height, dry matter accumulation, leaf area index, relative growth rate, net assimilation rate, primary and secondary branches per plant and seed yield of Indian mustard.

Mandal *et al.* (2006) conducted an experiment on the assessment of irrigation and nutrient effects on growth, yield and water use efficiency of Indian mustard (*Brassica juncea*) in central India. They reported that the application of organic manure along with 100% NPK fertilizers could reduce the need for one post-sowing irrigation without compromising the yield of this crop under deficit irrigation.

Bonde *et al.* (2005) reported that the highest seed yield was recorded in treatment I_5 (irrigations during pre -sowing, vegetable, branching, 50% flowering, siliqua formation and seed filling stages) and water use efficiency was highest in treatment I_4 (two irrigations given at pre-sowing and at 250mm CPE), while it was lowest in I_5 treatment. They also reported that the highest consumptive use, absolute and relative water use rates were recorded in I_5 while the lowest values were recorded in I_4 treatment.

Panda *et al.* (2004) conducted an experiment during winter season of 1997-98 in New Delhi, India, to study the effect of irrigation levels and sowing dates on crop physiological and yield parameters of Indian mustard cultivars SEJ 2 and pusa Bold. They reported that pusa Bold was superior to cultivars SEJ 2 in terms of crop physiological characters and yield.

Agrawal *et al.* (2003) conducted a field experiment during *rabi* seasons of 1994-95 and 1995-96 on the farm of Indian Agricultural Research Institute, New Delhi to study the growth, yield and yield contributing characters of wheat inter-crops of chickpea and mustard under different frequency (IW/CPE 0.4, 0.8) and salinity levels (EC 6 and 12 dSm^{-1}) of irrigation water. Mustard growth characters of plant height, dry matter, number of branches and yield attributes of siliqua number, seeds per siliqua increased at EC 6 dSm^{-1} but decreased at EC 12 dSm^{-1}. However, test weight increased with salinity and decreased with irrigation frequency. The mustard yield increased significantly at EC 6 dSm^{-1} and also at Ee 12 dSm^{-1} though non-significantly in comparison to control. The yield also increased with increasing irrigation levels.

Raut *et al.* (2003) observed that the effect of five levels of irrigation (I_0noirrigation,I_1=pre-flowering,I_2=pre-flowering+50%flowering,I_3=pre-flowering+50%flowering+seedfilling,I_4=preflowering+50%flowering+seed filliling + siliqua setting stage) on the growth and yield attributes of Indian mustard cv. pusa Bold reported that I_3 resulted in the highest number of siliqua $plant^{-1}$ and seed yield.

Bharati and Prasad (2003) observed the effect of irrigation (based on irrigation water depth to cumulative pan evaporation ratio or IW:CPE) on the performance of Indian mustard and found that the highest seed yield (1.59 t ha^{-1}) and oil content (41.87%) were obtained with irrigation at 0.4

1w:CPE (twice at 5-cm depth) compared with 0.8 IW:CPE (once at 10cm depth).

Giri *et al.* (2003) conducted an experiment with mustard (*Brassica juncea)* to evaluate the effect of five levels of irrigations (I_0= no irrigation, I_1 = pre-sowing, I_2 = pre-sowing + vegetative branching, I_3 = pre-sowing + vegetative branching + 50% flowering, I_4 = pre-sowing + vegetative branching + 50% flowering+ grain filling stage) and reported that irrigation at I_4 level increased the values of the yield and consumptive use of water.

Bharati *et al.* (2003) conducted an experiment on Indian mustard during 1999-2001 to study the effect of 3 irrigation levels based on the ratio of irrigation water depth: cumulative pan evaporation (IW : CPE) and 4 sulphur levels. The seed yield increased significantly up to an IW: CPE ratio of 0.8 (1.59 t ha^{-1}) with 2 irrigations each of 5 cm depth. However water-use efficiency was higher at 0.4 ratio with 1 irrigation. Response to sulphur was recorded up to 30 kg S ha^{-1} which was at par both with 15 and 45 kg S ha^{-1}. Plant height, dry matter $plant^{-1}$ and length of siliqua increased significantly up to 0.4 IW: CPE ratio and 15 kg S ha^{-1}.

Majid and Simpson (2002) observed in an experiment with mustard (*Brassica juncea L.cv.Cutlass*) that the effect of three irrigation regimes (triple, double and single) as well as under dry conditions on its growth pattern and yield resulted that the seed yield was increased to 4002 kg ha^{-1} under irrigation compared to 2551 kg ha^{-1} under dry condition.

Sing and Saron (1993) conducted a field experiment to study the effect of irrigation and observed that the yield of toria was beneficially affected by irrigation at IW/CPE ratio of 0.2.

Singh *et al.* (1993) reported in an experiment that toria significantly responded to irrigation levels and two levels of irrigation at branching and siliqua development stage produced the maximum seed yield of 13.57 t ha^{-1} where those levels of irrigation at branching and flowering stage produced the lower seed yield.

Gill and Narang (1991) observed in an experiment with rabi season that all growth parameters and seed yield significantly increased, while irrigation was applied at 20 days after sowing under cumulative pan evaporation of 80mm.while irrigation was applied at 20 days after sowing under cumulative pan evaporation of 80mm.

Rarihsr (1990) found in an experiment with mustard that the seed yield and yield components were greater while irrigation was applied at irrigation depth: cumulative pan evaporation of 0.6.

Sharma and Kumar (1990) observed that one or two levels of irrigation produced the seed yields of 1.11 and 1.377 t ha^{-1} respectively in 1984-85. The corresponding values were 1.26 and 1.38 t ha^{-1} in 1985-86.Yield was obtained 0.95 and 0.71 t ha^{-1} without irrigation in the years respectively.

Sharma and Kumar (1989b) conducted an experiment with *Brassica juncea cv.* Krishna and irrigated the crop with two levels. They observed that number of seeds $siliqua^{-1}$, 1000-seed weight and seed yield was higher, when irrigation was applied at irrigation depth and cumulative pan evaporation ratio of 0.6. Number of seeds $siliqua^{-1}$, 1000-seed weight and seed yield was lower with irrigation to a ratio of 0.4 or without irrigation.

Lal *et al.* (1989) irrigated mustard cv. varuna with one to three levels at different growth stages in an experiment. They found that application of one level of irrigation with at flowering stage gave the highest seed yields. They further, observed that irrigation with one to three levels gave seed yields of 1.11-1.36 t ha^{-1} where seed yield was obtained 0.97 t ha^{-1} under rainfed conditions.

Parihar and Tripathi (1989) gave irrigation to mustard(*Brassica juncea)* with 6-cm water/irrigation and found that average yields were 0.69,1.00 and 1.05 t ha^{-1} in 1982-1983 for irrigation depth and cumulative pan evaporation ratios of 0.4, 0.6 and 0.8, respectively.

Rathore and Manohar (1989) conducted two experiments from 1984-86 with mustard (*Brassica juncea)* and they applied 0 to 400 kg ha^{-1} of sulphur (as elemental S) and 0 to 180 kg ha^{-1} of nitrogen (as urea). They found that in the case of sulphur, number of primary branches $plant^{-1}$ increased up to 160 kg S ha^{-1} and also oil content of seed increased significantly with the increase of sulphur rates up to 160 kg ha^{-1}.

Koti *et al.* (1989) conducted field trials at Dharwad in 1989. Mustard was given 0 to 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} applied. Siliqua yield was significantly affected by the rate of sulphur.

Shrivastava *et al.* (1988) observed in an experiment with mustard (*Brassica juncea) cv.*varuna that two irrigations at pre-flowering and seed development stages gave higher harvest index. They also observed that irrigation at pre flowering stage gave higher harvest index than that given by irrigation at seed development stage of without irrigation.

Sharma and Kumar (1988) irrigated mustard (*Brassica juncea)* with 60cm water/irrigation water depth: cumulative pan evaporation ratio of 0.4 or 0.6 (one and two irrigations respectively) and reported that seed yields were 1.31 and 1.46 t ha^{-1} in 1984-85 and 1.03 and 1.23 in 1985-86 respectively compared with respective yields of 0.82 and 0.71 under rainfed conditions.

Sharma and Giri (1988) reported that *Brassica juncea* grown with 0-80 kg N ha^{-1} under rainfed conditions or with one-two irrigations gave similar seed yields of 0.8-1.5 t ha^{-1} in 1984-85 and 1.40-1.50 t ha^{-1} in 1985-86.

Sarker and Hassan (1988) made an experiment with *Brassica juncea* at two locations in Bangladesh. They irrigated the crop at one to six levels commencing 20-25 days after sowing and observed that the highest seed yield at BINA farm 1.29 t ha^{-1} with three levels of irrigation and that at BARS Ishurdi farm was 1.18 t ha^{-1} with five irrigations. Siliqua plant $^{-1}$, number of seeds $siliqua^{-1}$ and 1000-seed weight were increased with increasing levels of irrigation.

Mondal *et al.* (1988) obtained from a field experiment with *Brassica juncea cv.* T-59 irrigated with 14 levels revealed that the maximum yields with one irrigation at flowering and siliqua stages were 2.56 and 4.46 t ha^{-1} and with three irrigation supplied at pre-flowering, early and late siliqua stages were 2.06 and 2.10 t ha^{-1} in 1981 and 1982, respectively.

Prasad and Ehsanullah (1988) pointed out in an experiment in 1983-85 with *Brassica juncea* that two irrigations with 6cm water/irrigation at irrigation water depth: cumulative pan evaporation ratio of 0.8 or at 30 and 60 days after sowing gave seed yields of 1.81-1.83 t ha^{-1} compared to

1.18-1.49 t ha^{-1} with one irrigation and 0.99-1.05 t ha^{-1} without irrigation. Irrigation also increased seeds $siliqua^{-1}$ and 1000-seed weight.

Katole and Sharma (1988) conducted a field experiment on clay loam soils to study the effect of irrigation schedule and found that yield was highest with two irrigations one at branching and other at siliqua development stage.

Reddy and Sinha (1987) observed in an experiment with *Brassica juncea* in the Rabi seasons of 1983-1985 that irrigation at IW/CPE ratio of 0.6 and 0.3 (three and one irrigation respectively) gave average seed yields of 1.79 and 1.64 t ha^{-1}, respectively compared to 1.5 t ha^{-1} from the rainfed crops.

Singh and Srivastava (1986) stated that irrigation with one level at flowering bud stage and with two levels at the siliqua formation stage gave 430 kg ha^{-1} seed yield of mustard where seed yield was 330kg ha^{-1} without irrigation.

Roy and Tripathi (1985) recorded that the growth characters and yield of *Brassica juncea* were significantly increased with irrigation at IW:CPE (irrigation water depth: cumulative pan evaporation) ratio of 0.6 compared to irrigation at IW:CPE ratio of 0.4. Yield was positively associated with number of branches and siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$ and 1000-seed weight.

Singh (1983) found in an experiment with mustard (*Brassica juncea)* grown with a pre-sowing irrigation in the Rajasthan arid zone that irrigation at the pre-flowering stage increased the yield of mustard from

0.62 to 1.17 t ha^{-1}. But the irrigation given at siliqua formation stage did not increase seed yields.

Chaniara and Damor (1982) recorded that seed yield of mustard of (*Brassica juncea)* with five irrigations applied at 25-day intervals and seven irrigations at 15-day intervals were similar but higher than those with five irrigations at 35-day intervals.

Singh and Yusuf (1979) reported that seed yield of brown season (*Brassica campestris* var. *dichotoma*) was curvilinearly related to irrigation levels reaching a maximum yield, and response to nitrogen was greater with irrigation than without irrigation.

Joarder *et al.*(1979) working with mustard cv. Rai 7, Laha 101 and Rai 5 cultivated under irrigated or rainfed condition observed that irrigation increased the number of primary and secondary branches, siliquas and $siliqua^{-1}$ and therefore, increased yield $plant^{-1}$ and yield ha^{-1} by 65 and 59% compared to the rainfed treatments, respectively.

Clark and Simpson(1978) observed in an analysis of yield components of rape under field conditions for two years at Saskatoon that irrigation scarcely affected the number of branches and increased number of siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$ and 1000-seed weight. The seed yield was 1.65 t ha^{-1} and 2.55 t ha^{-1} for rainfed, low and high irrigation, respectively correlated with 1000-seed weight in both years.

2.2. Effect of sulphur on mustard

Sulphur is a secondary nutrient occurring in soil both in organic and inorganic forms. The average sulphur content of the earth's crust is 0.06-0.10%. The main sulphur bearing minerals are gypsum ($CaSO_4$. $2H_20$), epsomite ($MgSO_4.7H_20$), mirabilite (Na_2SO_4. $10H_20$), pyrite (FeS_2) and sphalerite (ZnS). Plants absorb S in the form of SO_4^{-2}, which is present either in soil solution or adsorbed on soil colloids (clay and humus). Sulphur carries out many important functions for plant growth. Sulphur is involved in the synthesis of amino acids (cystine, cysteine and methionine), coenzyme A, biotine, thiamine (Vit B1) and chlorophyll. It is a vital part of ferrodoxins. It is responsible for characteristic taste and smell of plants like onion and mustard.

Ray *et al.* (2015) conducted field experiments on clay loam soil during winter season of 2010–2011 and 2011–2012 at the Research Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to study the influence of sulphur (S) levels and irrigation on quality and yield of mustard (cv. Varuna, T-59). Results revealed that yield attributes and yield of crop were highest with 60 kg S ha^{-1}, mostly at par with 45 kg S ha^{-1}. The erucic:oleic acid ratio was inversely related to the subsequent increase in S doses, thereby suggesting the qualitative improvement of oil with S application. Oil percent has a negative correlation with sinigrin and gluconapin content. The uptake of S was positively correlated with oleic acid content but showed lower or even negative correlation with other fatty acids.

Raman *et al.* (2015) conducted an experiment during winter season of 2010-11 and 2011-12 with mustard (*Brassica Juncea* (L.) Czernj and

Cosson) on sandy loam soil at Agricultural Research Farm of Raja Balwant Singh College, Bichpuri, Agra to find out the response of mustard to sulphur in relation to Iron. The treatments consisted of four doses of iron (0, 10, 20 and 40 kg ha^{-1}) and four doses of sulphur (0, 30, 60 and 90 kg ha^{-1}) applied threw ferrous sulphate and elemental sulphur. Seed and stover yield of mustard increased significantly up to 20 kg Fe ha^{-1} and 60 kg S ha^{-1} application. Application of 40 kg Fe ha^{-1} and 90 kg S ha^{-1} significantly increased growth and yield attributing characters. The total uptake of N, P, K and S significantly increased up to 20 kg Fe ha^{-1} and 90 kg S ha^{-1}.

Mallick *et al.* (2015) conducted a field experiment comprising three levels each of phosphorus (0, 30 and 60 kg P2O5 ha^{-1}) and sulphur (0, 20 and 40 kg S ha-1) was conducted during the winter seasons for two consecutive years of 2007-08 and 2008-09 at farmers field of Pingla block in Pashcim Medinipur district of West Bengal to study the contribution of these nutrients in improving yield components and yield of rapeseed crop [*Brassica campestris var yellow sarson*] cv. 'B-9' on medium deep loam soil having medium in available P and S. The results revealed that successive increase in P and S increased yield attributes and seed yield of yellow sarson crop. The increase in seed yield was significant up to 40 kg S ha^{-1}.

Malviya *et al.* (2014) conducted a field experiment at Rajaula Agricultural Research farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.) during rabi season 2011 on sandy- loam soil having pH 7.8 to assess the effect of nitrogen, sulphur and boron on mustard (*Brassica juncea* L.) under rainfed condition with eighteen treatment combination 2N-levels (40 and 80 kg ha^{-1}), 3S-levels

(20,40 and 60 kg ha^{-1}) and 3B–levels (control, one spray 300 ppm at 40 DAS and two spray 300 ppm at 40 and 60 DAS. Sulphur application at the rate of 40 kg S ha^{-1} performed better than lower dose of 20 kg S ha^{-1} in respect of growth and yield of mustard.

Yadav *et al.* (2014) conducted a field experiment entitled Effect of phosphorus and sulphur on growth, yield and economics of Indian mustard (*Brassica juncea* coss.) was carried out at farmer field of Ballia District (U.P.), India during the *rabi* season of 12-13. The experiment was laid out in Randomized Block Design having three levels of phosphorus (20, 40 and 60 kg ha^{-1}) and sulphur (20, 30 and 40 kg ha^{-1}) each with three replications. The sulphur was applied through SSP and gypsum, respectively. The plant height, dry weight per plant, number of siliqua plant-^{1}, seed yield and stover yield increased significantly at 40 kg sulphur ha^{-1}, over lower doses of sulphur. Application of 40 kg sulphur ha^{-1} gave the higher plant height (100.38 and 101.00 cm), dry weight $plant^{-1}$ (16.96 and 17.04 g), number of siliqua $plant^{-1}$ (570.54 and 566.55), number of seed $siliqua^{-1}$ (13.09 and 13.49), seed yield (15.44 and 15.62 q ha^{-1}), stover yield (35.26 and 35.67 q ha^{-1}) and net return (Rs. 32,891.6 ha^{-1}), respectively. Oil content increased significantly with the application of 40 kg sulphur ha^{-1}.

Yeasmin *et al.* (2013) conducted that a field experiment on rapeseed a comprising of four levels of sulphur (0, 30, 35 and 40 kg S ha-1) and three levels of boron (0, 1and 2 kg B ha^{-1}) was conducted at Rajshahi, Bangladesh to study the contribution of sulphur and boron in improving yield and yield components of rapeseed. The highest number of branches $plant^{-1}$ (14.83), pods $plant^{-1}$ (109.5), total seeds $siliqua^{-1}$ (12.70), normal seeds $siliqua^{-1}$ (11.72) and the lowest number of deformed seeds $siliqua^{-1}$

(0.924) were obtained from 30 kg S ha^{-1}. In this experiment, 30 kg S ha^{-1} also produced higher 1000-seed weight (2.90g), seed yield (2.09 t ha^{-1}), straw yield (6.04 t ha^{-1}) and biological yield (8.12 t ha^{-1}).

Dubey *et al.* (2013) conducted the experiment at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Faizabad (Uttar Pradesh), during the rabi season of 2008-09 in RBD and replicated three times. The treatments comprised four levels of sulphur (0, 20, 40 and 60 kg S ha^{-1}) and four levels of zinc (0, 5, 7.5 and 10 kg Zn ha^{-1}). The mustard variety “Varuna” was used as test crop. Application of 60 kg S ha^{-1} and 10 kg Zn ha^{-1}, produced significantly higher plant, primary and secondary branches plant^{-1}, number of leaves plant^{-1}, days taken to flowering, days taken to maturity, number of siliqua plant^{-1}, length of siliqua, and number of seeds siliqua^{-1}, harvest index and oil content. However, dry matte accumulation plant^{-1}, 1000-grain weight (g), biological yield, seed yield, stover yield and protein content significantly increased with increasing dose of sulphur up to 40 kg and zinc 7.5 kg ha^{-1}.

Piri (2012) conducted to Study of yield and yield components of black mustard (*Brassica nigra*) in condition of sulphur fertilizer application and water stress, a field experiment was conducted at research farm of Payame Noor University of Zahedan during crop season of 2010-11. The treatments consisted of three levels of irrigation: no irrigation, one irrigation at 45 days after sowing (DAS) and two irrigations at 45 DAS and 90 DAS, in main plots and four levels of sulphur: 0, 15, 30 and 45 kg S ha^{-1}, in sub-plots. The increasing level of sulphur increased dry matter accumulation, seed and biological yield and harvest index.

Raman *et al.* (2012) a field experiment was conducted during winter season of 2008-09 and 2009-10 on sandy loam soil Bichpuri, Agra to find out the effect of sulphur levels on growth, yield and quality of Indian mustard [*Brassica juncea* (L.), Czernj and Cosson] genotypes. The treatments consisted of four genotypes (Pusa Bold, 'Rohini', 'Varuna' and 'Kranti') of mustard and four levels of sulphur (0, 30, 60 and 90 kg ha^{-1}) applied through elemental sulphur. Pusa Bold genotype recorded the highest seed yield of 2.05 and 2.09 t ha^{-1} followed by 'Varuna', 'Rohini' and 'Kranti' respectively. Significant response was observed up to 90 kg S ha^{-1} in seed and stover yield. Oil content and nutrient uptake were also highest under this treatment.

Begum *et al.* (2012) conducted field experiments at the Central Research Station of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gajipur during the period from November to February in 2004-05 and 2005-2006 to evaluate the effect of different doses of sulpher (0, 20, 40, 60 and 80 kg ha^{-1}) on rapeseed variety BARI sarisha-15. Results showed that the most of the growth parameters and yield attributes were significantly influenced by different levels of sulpher. The growth parameters, yield and yield contributing characters were increased with the increasing levels of sulpher fertilizer upto 60 kg ha^{-1} and with the doses beyond that were found to decrease. All growth parameters like plant height, leaf area, dry matter accumulation, leaf area index, crop growth rate, relative growth rate and all all yield components such as number of siliqua per plant, seeds per siliqua, 1000-seed weight and seed yield per plant were found maximum from the treatment with 60 kg ha^{-1}. The highest seed yield (1990 and 1896 kg ha^{-1}) was found when sulpher was used at the rate of 60 kg ha^{-1}.

Raouf Seyed Sharifi (2012) conducted an experiment to study of yield, yield attribute and dry matter accumulation of canola (*Brassica napus* L.) cultivars in relation to sulfur fertilizer, a split plot experiment based on randomized complete block design was conducted in 2007 at the Research Farm of Islamic Azad University, Ardabil Branch. Factors were various levels of sulfur fertilizer (0 as control, 25, 50 and 75 kg S ha^{-1}) as granular from potassium sulphate in the main plots, while canola cultivars (Fornax, Opera and Slmo) were allocated at random in the sub-plots. The results showed that various levels of sulfur fertilizer affected grain yield, plant height, harvest index, grain per pod and pod per plant significantly. Maximum of these characteristics were obtained by the plots which received 75 kg S ha^{-1}.

Verma *et al.* (2012) conducted a field experiment during rabi season of 2008-09 and 2009-10 at the Students' Instructional Farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur to evaluate the effect of sulphur (0, 20, 40 and 60 kg S ha^{-1}), zinc (0, 5 and 10 kg Zn ha^{-1}) and boron (0, 0.5 and 1.0 kg B ha^{-1}) levels on quality, economics and uptake of nutrients in mustard [*Brassica juncea* (L.) Czern & Coss]. Results revealed that application of 60 kg S ha^{-1} gave significantly higher seed yield, economics, oil yield, protein yield and nutrients uptake (kg ha^{-1}) than control, 20 and 40 kg S ha^{-1} during experimental years.

Bharose *et al.* (2011) conducted a field experiment during Rabi season 2008 to Study the effect of different levels of phosphorus and sulphur on availability of N, P, K, protein and oil content in Toria (*Brassica Sp.*)Var.P.T.-303 on crop research farm Department of Soil Science and

Agricultural Chemistry, Allahabad Agricultural Institute- Deemed University, Allahabad. The design applied for statistical analysis was carried out with 3^2 factorial randomized block design having two factors with three levels of Phosphorus 0, 25 and 50 kg ha^{-1}, and three levels of Sulphur 0, 20, and 40 kg ha^{-1}, respectively. During the course of experiment, observations were recorded as mean values of the data showed that there was significant increase in % Nitrogen, %Phosphorus, % Potassium, % protein and oil content in treatment combination (50.00 kg phosphorus + 40.00 kg sulphur ha^{-1}) and followed by (25.00 kg Phosphorus + 20.00 kg Sulphur ha^{-1}), respectively over than (control).

Khatkar *et al.* (2009) conducted a field experiment during the winter season of 2004-2005 at Agricultural Research Farm, Allahabad. The experiment consisted of three factors namely nitrogen (80 and 100 kg ha^{-1}) and sulphur (10, 20 and 30 kg ha^{-1}), phosphorus (40 and 60 kg ha^{-1}) with blanket application of potash at 40 kg ha^{-1}. Highest plant height and maximum plant dry weight was recorded with higher doses of these factors. Also, more number of siliqua $plant^{-1}$, seed $siliqua^{-1}$ and the test weight was also recorded with higher levels of these factors which ultimately resulted in higher seed yield.

Khalid *et al.* (2009) conducted a field study to assess the effect of different sulfur (S) fertilizers on rapeseed crop and plant available S (SO4-S) status of two S-deficient soils. These soils were located in Pothwar, rainfed areas of Pakistan. Three S fertilizers were applied at five different levels (0, 10, 20, 30 and 40 kg S ha^{-1}). The three S fertilizers increased the rapeseed yield and yield parameters in order of ammonium sulphate (AS) > single super phosphate (SSP) >gypsum, though their effect was at par with each another. The 40 kg S ha^{-1} produced highest biomass (9058 kg ha^{-1}), seed yield (1656 kg ha^{-1}) and plant S content (0.158 g 100 g^{-1}), but these increases were statistically at par with that of 30 kg S ha^{-1}. The highest mean S uptake of 17.0 kg ha^{-1} was recorded in soil fertilized with AS at 30 kg ha^{-1}.

Kabiraj (2007) conducted an experiment with the 5 levels of sulphur *viz.* 0, 10, 20, 30 and 40kg S ha^{-1}. Sulphur significantly increased the plant hieght, highest number of branches $plant^{-1}$, highest number of filled siliqua $plant^{-1}$, longest siliqua, highest 1000-seed weight, highest seeds $siliqua^{-1}$, highest straw yield, highest biological yield and highest seed yield with 30 kg S ha^{-1}.

Malviya *et al.* (2007) conducted a field experiment during rabi season of 2002-03 to study the effect of Nitrogen, Sulphur and Boron on growth and yield of Indian mustard var. PRO-4001. Sulphur applied at rate of 60 kg ha^{-1} produced significantly higher oil and protein content as well as oil yield over 30 kg S ha^{-1}. Application of 300 ppm boron through foliar spray at 40 and 60 DAS produced significantly higher seed and oil yield than one spray at 40 DAS and control.

Ahmed *et al.* (2007) conducted a field experiments at Cereal Crops Research Institute, Pirsabak, Nowshera, Pakistan, during winter 2003-2004 and 2004-2005 to evaluate the effect of nitrogen and sulfur levels and methods of nitrogen application on canola (*Brassica napus* L. cv. Bulbul-98) under rainfed conditions. Four levels of S (0, 10, 20, and 30 kg ha^{-1}) and three levels of N (40, 60, and 80 kg ha^{-1}) and a control treatment with both nutrients at zero level were included in the experiments. Sulfur levels were applied at sowing. Oil content increased significantly up to 20 kg S ha^{-1} but further increase in S level did not enhance oil content. Protein content increased from 22.4% to 23.2% as S rate was increased from 0 to 20 kg ha^{-1}.

Ahmad *et al.* (2007) conducted an experiment with 4 levels of S *viz.* 0, 10, 20 and 30 kg ha^{-1}. Oil content increased significantly up to 20kg S ha^{-1} but further increase in S level did not enhance oil content.

Malhi *et al.* (2007) field experiment was conducted on a S-deficient Gray Luvisol (Boralf) soil near Star City, in northeastern Saskatchewan, to determine yield, seed quality and S uptake response of different *Brassica*. A total of 20 treatments were tested in a factorial combination of four oilseed crops *(Brassica juncea* canola cv. Arid, *Brassica juncea* canola cv. Amulet*, Brassica juncea* mustard cv. Cutlass, and *Brassica napus* cv. In Vigor 2663 hybrid canola) and five rates of potassium sulfate fertilizer (0, 10, 20, 30, and 40 kg S ha^{-1}). Species/cultivars responded positively for seed yield and most other parameters to S fertilizer. Seed yield was usually maximized at the rate of 30 kg S ha^{-1}.

Piri and Sharma (2006) reported that seed yield of mustard increased significantly with increasing levels of application of sulpher significantly increased the plant height, dry matter accumulation, leaf area index, relative growth rate, net assimilation rate, primary and secondary branches per plant and seed yield of Indian mustard. They also reported that a significant response was observed upto 45 kg S ha^{-1}.

Saifullah *et al.* (2006) conducted an experiment with the 4 levels of sulphur *viz.,* 0, 9, 18 and 27kg S ha^{-1}. Application of sulphur at the rate of 18 kg ha^{-1} gave the highest seed yield, pods $plants^{-1}$, 1000-seed weight, stover yield and biological yield

Krisna *et al.* (2005) observed in an experiment with mustard (*Brassica juncea*) and determined the effect of three levels of sulphur (0, 30, and 60 kg ha^{-1}) on the quality of mustard and reported that oil, glucosinolate and protein content were higher at 60 kg S ha^{-1}.

Kumar *et al.* (2005) reported that salt stress showed significant reduction in plant water status in terms of relative water content, leaf water potential and leaf osmotic potential. They also reported that both P and S fertilizers individually improved the yield under saline conditions upto some extent.

Singh *et al.* (2004) conducted a field experiment during the winter season of 1996–97 and 1997–98 at Agricultural Research Sub Station, Kumher (Bharatpur), to study the effect of N and S on seed yield, plant height, primary and secondary branches and dry-matter accumulation of Indian mustard [*Brassica juncea* (L). Czernj. and Cosson]. Nitrogen at the rate of 80 kg ha^{-1} + S at the rate of 60 kg ha^{-1} significantly increased siliqua $plant^{-1}$, seeds $siliqua^{-1}$, length of siliqua and test weight of seeds and also resulted in highest seed (2,109 kg ha^{-1}) yield on pooled basis. On pooled basis, optimum dose of N and S was 88.24 and 74.86 kg ha^{-1} respectively.

Rana *et al.* (2004) conducted a field experiment to evaluate the response of sulphur on mustard (*Brassica juncea*) cv. They studied the effect of 3 levels sulphur (0, 20 and 40 kg S ha^{-1}). 20 kg S ha^{-1} produced highest significant yield.

Kumer *et al.* (2004) reported that the Indian mustard variety responded significantly to the application of sulphur. Seed yield and oil yield increased significantly with sulphur addition. The seed yield (17.72q ha^{-1}) was obtained from 40 kg S ha^{-1} which was 12.4% higher than that obtained in the control.

Raut *et al.* (2003) conducted an experiment that the effect of four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) on the growth and yield attributes of Indian mustard cv. Pusa Bold. They reported that the highest number of siliqua plant^{-1}, seed yield plant^{-1}, plant height and number of branches plant^{-1} were produced from 40 kg S ha^{-1}.

Malekuzzaman (2002) reported that the highest number of primary branches plant^{-1} was produced by Tori-7 with application of 30 kg S ha^{-1}. The highest number of seed siliqua^{-1} and highest 1000-seed weight was observed with the application of S upto 45 kg ha^{-1}.

Suresh *et al*. (2002) conducted a field experiment in Uttar Pradesh, India to study the effect of Indian mustard cv. Varuna to various levels of S application (0, 20, 40 and 60 kg ha^{-1}). Sulphur at 60 kg ha^{-1} produced the highest seed (1.809 kg ha^{-1}) and oil (0.756 kg ha^{-1}) yields, siliqua number plant^{-1} (475.85), siliqua length (6.17 cm), seed number siliqua^{-1} (13.42), 1000-seed weight (4.43 g) and N (108.58 kg ha^{-1}), P (16.77 kg ha^{-1}), K (85.06 kg ha^{-1}) and S (33.77 kg ha^{-1}) uptake. The highest benefit cost ratio (2.03 4) was obtained at 60 kg S ha^{-1}.

Miah *et al.* (2001) conducted an experiment with high yielding varieties of mustard (BINA sarisha-1, BINA sarisha-2, Sonali sarisha and BARI sarisha-6). Five doses of S (0, 15, 30, 45 and 60 kg ha^{-1}) were used. Seed yield of all the test varieties increased significantly due to S application, upto 45 kg ha^{-1}.

Chaubey *et al.* (2001) studied a field experiment to evaluate the response of mustard (*Brassica juncea*) cv. Rohini to phosphorus (0, 40 and 60 kg $P_2 0_5$ ha^{-1}) and sulphur (0, 15, 30, 45 and 60 kg S ha^{-1}) fertilization. The growth attributes (slliqua plant^{-1}, seed siliqua^{-1} and 1000-seed weight) increased significantly with increasing level of P and S upto 60 kg $P_2 0_5$ and 30 kg S ha^{-1}. Sulphur increased the seed yield by 17.06, 14.68 and 22.7%, respectively.

Singh *et al.* (2000) observed from eight improved strains of *Brassica spp*. to four levels S (0, 15, 30 and 45 kg ha^{-1}). Application of S upto 45 kg ha^{-1} significantly increased the oil content, seed yield and yield attributes compared to its lower levels. Application of S upto 45 kg ha^{-1} also increased the mean return and benefit cost ratio.

Bhagwan *et al.* (2000) applied various sulphur levels 0, 20, 40 and 60 kg ha^{-1} and three Indian mustard Varuna, Vardan and Narenda. Narendra Rai-1 and Varuna produced higher plant height, number of branches plant^{-1}, number of siliqua plant^{-1}, and number of seed siliqua^{-1}, 1000-seed weight, seed and stover yield. They further stated that the application of 40 and 60kg S ha^{-1} produced significantly higher yield and quality then the application of 20 kg S ha^{-1}.

Jackson (2000) observed experiment with three levels of application of sulphur (0, 22 and 45kg S ha^{-1}). It was recorded that a dose of 20kg S ha^{-1} was adequate for optimum seed and oil yields.

Mondal (2000) carried out a field experiment in winter of 1996-97 and 1997-98 at Rajouri with *Brassica campestris* cv. Kos-1 was given 0 to 40 kg S ha^{-1}. Seed yield increased by sulphur application.

Mahapatra *et al.* (1999) conducted from a field experiment during winter 1996-97 on sandy loam soils at Kalyani, West Bengal, India, and rape cv. B-9 toria (*Brassica campestris* var. toria) cv. C-3 and T-9 and mustard (*Brassica juncea*) cv. RW-351 were given 0, 20, 40 and 60 kg S ha^{-1}. Seed yield and yield components values were highest in mustard and were increased in all genotypes by S application.

Khan *et al.* 1999 reported that from a field study during Rabi season 1988-89 and 1989-90 at Kanpur, Uttar Pradesh, India, mustard (*Brassica juncea*) cv. Kranti, Varuna and Rohini were given 0, 10, 20 and 30 kg S ha^{-1}. The highest seed and oil yields were obtained with Kranti using 20 kg S ha^{-1}

Ahmad *et al.* (1998) carried out an experiment with *Brassica juncea* cv. Pusa Jaikisan and *Brassica campestris* cv. Pusa and Gold were given 0, 40 or 60 kg S ha^{-1}. They reported that application of 40kg S ha^{-1} increased yield components, seed and oil yield, respectively. Percentage oil content of seed was highest with 60 kg S in both cultivars.

Singh *et al.* (1998) reported that protein content of mustard (*Brassica juncea* L.) increased significantly with the increasing level of S from 0 to 90 kg ha^{-1}

Sarkar *et al.* (1997) reported that increasing rates of applied S (as ammonium sulphate) from 0-45 kg ha^{-1} increased the seed yield from 1.46 to 1.82 t ha^{-1} in *Brassica juncea* cv. Varuna and from 1.36 to 1.77 t ha^{-1} in cv. RW 351; oil increased from 586 to 779 kg ha and from 552 to 730 kg ha^{-1}, respectively. Sulphur at 60 kg ha^{-1} slightly decreased seed yields but increased oil yields.

Tamak *et al.* (1997) observed in a field trail on sunflower using 0, 30, 60 and 90 kg P_2O_5, 0, 25, and 50 kg S ha^{-1} along with 0.28ppm boron sprayed and not sprayed. Seed yield increased significantly with upto 60 kg P_2O_5, and 25 kg S along with foliar application of boron. Oil content of seed was increased by all fertilizers, while protein content was increased by S but decreased by P and B.

Deekshitulu *et al.* (1997) observed that each successive increase in the level of sulphur from 0-50 kg S ha^{-1} significantly increased the seeds $siliqua^{-1}$.

Zhao *et al.* (1997) conducted 29 field trials in the U. K. to see the effect of S on rapeseed. It appeared that the glucosinolate concentration of rapeseed was usually higher when grown at the S-sufficient than the S-deficient sites. However, the addition of S fertilizer increased the glucosinolate concentration much more under S-deficient than under S-sufficient conditions. Further, they observed that there was a need to maintain a balanced N and S supply for both yield and quality.

Chauhan *et al.* (1996) observed that each successive increased in S levels from 0-50 kg S ha^{-1} significantly increased the number of grains $siliqua^{-1}$, branches $plant^{-1}$ and siliqua $plant^{-1}$ and 1000-seed weight.

Singh and Kumar (1996) reported that the application of S at rate of 40 kg ha^{-1} significantly increased the growth, yield attributes and yield of mustard compared with 0 to 20 kg S ha^{-1}.

Das and Das (1995) observed that sulphur application had no significant effect on growth and yield attributes except seeds $siliqua^{-1}$ and 1000-seed weight; however, it had a marked effect on oil content, and seed and oil yields. The increase in oil content due to 45 kg S ha^{-1} was 12.5%

compared with control of S. The highest seed yield was obtained with 45 kg S ha^{-1} and the magnitude of increase at this level compares with 0, 15 and 30 kg S ha^{-1} was 23.1, 16.2 and 11.1% for seed yield, respectively.

Das *et al.* (1994) in an experiment, with four levels of S (0, 20, 40 and 60 kg ha^{-1}) found in sunflower the highest S rate of 60 kg ha^{-1} produced higher oil and protein content over that of the control.

Sarker *et al.* (1993) worked with three high yielding varieties of mustard *viz.* BAU-M 248 (Sampad), M-257 (Sambol) and SS-75 (Sonali sarisha). They have applied five levels of sulphur *viz,* 0, 10, 20, 30 and 40kg S ha^{-1} .The variety Sampad followed Sambol in respect of seed yield at the same level of sulphur. Both the varieties M-257 and SS-75 (Sonali sarisha) gave the maximum seed yield at the rate of 40 kg S ha^{-1}.

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

Rajput *et al.* (1993) reported that application of 10-30 kg S ha^{-1} increased *Brassica juncea* seed yield compared with control. The highest yield was given by 20 kg S ha^{-1}.

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 S control.

Mohan and Sharma (1992) reported that seed yield of *Brassica juncea* cv. Pusa Bold increased with up to 50 kg S ha^{-1}. At further increasement of 25 kg S decreased seed yield. Oil yield followed a similar pattern to seed yield.

Gill and Palaskar (1992) conducted a pot experiment with *Brassica campestris* and different levels of S like 0, 20, 40 or 80 ppm as gypsum, elemental S or H_2S0_4, NPK was added as basal dose. Green fodder yield was highest with NPK + 40 ppm S as gypsum which was 51.3% greater than the yield with NPK only and 44.66% greater than the yield with no fertilizer. The treatment containing 20 ppm S as H_2SO_4 and 40 ppm elemental S also gave high yield.

Narwal *et al.* (1991) reported that grain and straw yields, total S uptake and oil yield increased with increasing S application rates. The highest seed and oil yields and S uptake were obtained with 120 ppm S as gypsum and the lowest with pyrites. In this experiment *Brassica juncea* cv. RH-30 was given 0, 30, 60, 90 or 120 ppm S as super phosphate, gypsum, press mud (filter cake) or pyrites.

Chowdhury *et al.* (1991) conducted a field experiment with varuna mustard during 1988-89. The treatments comprising 3 levels of S (0, 25 and 50 kg S ha^{-1}). Sulphur increased plant height, seed $siliqua^{-1}$, 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}.

On Farm Research Division (OFRD) of BARI (1990) summarized the effect of S along with various levels of NPK and concluded that the maximum yield of mustard varied with the S application (20 to 40 kg ha^{-1}) in different location of Bangladesh.

Ali *et al.* (1988) found that yield of mustard was 300% more at 40 kg S ha^{-1} over S control plots. Increase in yield due to S rates of 20 and 60 kg ha^{-1} were 226% and 317%, respectively.

Somani *et al.* (1988) carried out an experiment to study the effect of sulphur on the yield of *Brassica juncea* and found that increasing level of sulphur up to 50 ppm increased seed and straw yie1d.

Sawarkar *et al.* (1987) reported that increasing rates of applied S (as ammoniurn sulphate) from 0 to 45 kg ha^{-1} increased the seed yields from 1.46 to 1.82 t ha^{-1} in *Brassica juncea* cv. *Varuna* and from 1.36 to 1.77 t ha^{-1} in cv. RW 351; oil yields increased from 586 to 779 kg and from 552 to 730 kg ha^{-1}, respectively. Sulphur at 60 kg ha^{-1} slightly decreased seed yields but increased oil yields. Increasing rates of applied S from 0 to 60 kg ha^{-1} increased the available oil content in seeds from 40.46 to 45.05%, decreased average protein content from 18.84 to 17.48% and also decreased S content from 0.28 to 0.26%.

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

Singh *et al.* (1986) conducted a trial with mustard (*Brassica juncea*) on an alluvial soil given N, P and K fertilizers in addition to application of pyrites (FeS_2) at the rate of 400 kg ha^{-1} and found an increase of seed yield from 1.43 to 1.83 t ha^{-1} increased oil content of seed.

Varma and Reddy (1985) grew mustard (*Brassica juncea*) on an alluvial soil given P, K with 30-60 kg N ha^{-1} and 20-60 kg S ha^{-1} in 2 forms. The treatment 60 kg N + 60 kg S ha^{-1} gave the highest values for yield components, seed and oil yields. Sulphur as gypsum was superior to elemental S.

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

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

Rahman *et al.* (1984) reported that mustard crop was fertilized with S under irrigated condition; a maximum seed yield of 1.99 t ha^{-1} was obtained at 20 kg S ha^{-1} as against 1.06 and 1.85 t ha^{-1} with control and 30 kg S ha^{-1} application, respectively.

Nad and Goswami (1983) studied direct and residual effects of sulphur and magnesium were studied by in pot culture experiments in a three-crop sequence of legumes and oil seed on three alluvial soils in India. The residual effect of S was similarly beneficial to mustard.

Agarwal and Gupta (1982) carried out a pot experiment with *Brassica juncea* in an alluvial soil using pyrite (FeS_2) as sulphur source and found that the highest seed yield was produced in 200 kg ha^{-1} of pyrite and the highest seed oil content with Pyrite at 300-400 kg ha^{-1}.

Singh and Bairathi (1980) reported that the seed yields, oil and protein contents in seeds of *Brassica juncea* were increased with 45 kg S and 40 kg N ha^{-1}. They also reported that application of 30kg P_2O_5 ha^{-1} increased the yield.

Singh *et al.* (1970) reported that S requirement of oil crops was high. The yield of mustard was increased due to the application of S particularly in the form of gypsum.

Johanson (1970) conducted an experiment on winter rapeseed while the crop yielded 1.39 t ha^{-1} and increased plant height and growth with the application of 25 kg S ha^{-1} and the control gave 1.08 t ha^{-1}.

2.3. Effects of boron on mustard

Boron is a micronutrient requiring for plant growth relatively to a smaller amount. Plant absorbs B principally in the form of $H_3B0^-_3$ and to a smaller extent as $B_4O_7^{2-}$, $H_2BO^-_3$ and $HB0_3^{2-}$. The element plays a vital role in the physiological processes of plants such as cell maturation, cell elongation and cell division, carbohydrate, protein and nucleic acid metabolism, cytokinin synthesis, auxin and phenol metabolism. The functions of boron are primarily extracellular and related to lignifications and xylem differentiation membrane stabilization and altered enzyme reaction.

Dey *et al.* 2015 conducted the experiment at the East Ramchandraghat village of Khowai district of Tripura during 2014-2015 to evaluate the response of mustard to boron application. Boron application was made at 2 kg ha^{-1}. The seed yield was positively and significantly correlated with the yield contributing characters viz. pods $plant^{-1}$, seeds pod^{-1} and 1000-seed weight, but not with plant height and pod length. It is recommended that the farmers of Tripura can grow Mustard, var. Var. B-9 in boron deficient soils with a dose (2 kg ha^{-1}) of boron application.

Mallick *et al.* (2015) conducted a field experiment comprising two levels of boron (0 and 1 kg B ha^{-1}) was conducted during the winter seasons for two consecutive years of 2007-08 and 2008-09 at farmers field of Pingla block in Pashcim Medinipur district of West Bengal to study the contribution of these nutrients in improving yield components and yield of rapeseed crop [*Brassica campestris var yellow sarson*] cv. 'B-9' on medium deep loam soil having medium in available P and S. The results revealed that successive increase in B levels increased yield attributes and seed yield of yellow sarson crop. Boron application recorded marked improvement in seed yield (14.38%), uptake of P (12.75%), S (12.78%) and net returns (13.9%) and benefit: cost ratio (7.11) as compared to control.

Malviya *et al.* (2014) conducted with eighteen treatment combination 2N-levels (40 and 80 kg ha^{-1}), 3S-levels (20,40 and 60 kg ha^{-1}) and 3B–levels (control, one spray 300 ppm at 40 DAS and two spray 300 ppm at 40 and 60 DAS. Foliar application of boron with 300 ppm solution at 40 and 60 DAS improved growth and yield of mustard over no boron application.

Ara *et al.* (2014) conducted the experiment at the experimental Field of Sher-e-Bangla Agricultural University, Dhaka during the rabi season from November 2011 to February 2012 to investigate the role of nitrogen (N) and boron (B) on seed yield contributing characters and seed quality of rapeseed (*Brassica campestris* L.). The experiment was factorial with two factors, factor A consisted of four different N levels *viz.* 0, 60, 120, 180 (kg ha^{-1}) and factor B consisted of three different levels of B *viz.* 0, 1, 2 (kg ha^{-1}). The results of this study showed the significant increase of seed weight $plant^{-1}$, thousand seed weight and oil content percent to both N and B independently. But percent of germination failed to statistical differences to neither N nor B. The highest dose of B 2 kg ha^{-1} gave the highest value of seed weight $plant^{-1}$, 1000 seed weight and oil content percent.

Yeasmin *et al.* (2013) conducted that a field experiment on rapeseed a comprising of four levels of sulphur (0, 30, 35 and 40 kg S ha-1) and three levels of boron (0, 1and 2 kg B ha^{-1}) was conducted at Rajshahi, Bangladesh to study the contribution of sulphur and boron in improving yield and yield components of rapeseed. Maximum number of pods plant^{-1}, total seeds siliqua^{-1}, normal seeds siliqua^{-1}, 1000- seed weight, seed yield, straw yield and biological yield were produced from 1 kg ha^{-1} of B.

Choudhary *et al.* (2013) conducted a field experiment to study the responses of mustard cultivars to boron application at Directorate of Rapeseed Mustard Research Sewar, Bharatpur. Results revealed that mustard cultivar Laxmi recorded higher mean dry matter yield (11.95 q ha^{-1}) and lowest in vardan (11.17 q ha^{-1}). The dry matter yield of mustard cultivars increased significantly with increasing levels of boron application upto 20 kg borax ha^{-1} over control. The higher contents of B, Mn and Zn were noted in Laxmi cultivar, whereas Fe and Cu content was higher in Aravali cultivar of mustard. The contents of B, Fe, Mn, Cu and Zn in plants of mustard cultivars increased significantly with B application. Laxmi cultivar utilized the higher amounts of B, Mu, Cu and Zn in its plants. On the other hand, Vardan utilized the higher amounts of iron. The uptake of these micro nutrients increased significantly with B levels over control.

Verma *et al.* (2012) conducted a field experiment during rabi season of 2008-09 and 2009-10 at the Students' Instructional Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur to evaluate the effect of sulphur (0, 20, 40 and 60 kg S ha^{-1}), zinc (0, 5 and 10 kg Zn ha^{-1}) and boron (0, 0.5 and 1.0 kg B ha^{-1}) levels on quality, economics and uptake of nutrients in mustard [*Brassica juncea* (L.) Czern and Coss]. The application of 1.0 kg B ha^{-1} significantly increased seed yield, economics, oil yield, protein yield and nutrients uptake (kg ha^{-1}) of mustard over control and 0.5 kg B ha^{-1}.

Rashed *et al.* (2012) carried out a field experiment in non-Calcareous Floodplain Soil of Spices Research Sub-Station, Lalmonirhat under AEZ 2 during the rabi season of 2007-2008 and 2008-09. The objectives were to evaluate the effect of boron on the yield of mustard and to screen out the suitable variety tested against different boron levels for maximizing yield. Three varieties of mustard viz., BARI Sharisha-11, 13, and 14 and 5 levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}) along with a blanket dose of N120 P35 K65 S20 Zn3.0 kg ha^{-1} were used in the study. Results revealed that BARI Sharisha-11 performed better with 1.5 kg B ha^{-1} which produced 1.82 t ha^{-1} seed. However, from regression analysis, a positive but quadratic relationship was observed between seed yield and boron levels. The optimum dose of boron was appeared to be 1.7 and 1.6 kg B ha^{-1} for Lalmonirhat during 2007-08 and 2008-09, respectively.

Hossain *et al.* (2011) an experiment was conducted for three years from 2003-04 to 2005-06 to find out the optimum rate of B application for maximizing nutrient uptake and yield of mustard in calcareous soil of Jessore, Bangladesh. Boron was applied at 0, 1 and 2 kg ha^{-1}. The mustard variety BARI Sarisha-8, (*B. napus* group) was selected for the experiment. Effect of B was evaluated in terms of yield and mineral nutrients (N, P, K, S, Zn, and B) uptake. The mustard crop responded significantly to B application. The optimum rate of B was found to be 1 kg ha^{-1}. There was no significant difference between 1 and 2 kg B ha^{-1} in all the years. Seed yield and stover yield were significantly highest from 1 kg B ha^{-1}.

Ozturk *et al.* 2010 reported that the cultivars were grown under B moderate deficiency (extractable B 0.56 mg) and toxic B applied (15 kg B ha^{-1}). Toxic application reduced the seed yield and oil contents.

Tripathi *et al.* (2010) a field experiment was conducted at Pantnagar to study the effect of integrated nutrient management (INM) on Indian mustard (*Brassica juncea*). Twelve treatments consisting of recommended dose of fertilizers (RDF) i.e. 120-17.6–16.7 kg N-P-K ha^{-1} and 75% RDF alone or with addition of farmyard manure (FYM), sulphur (S), zinc (Zn), boron (B) and Azotobacter were tested in RBD with 3 replications. Application of 2 t FYM + 40 kg S along with RDF or 75% RDF resulted in significant increase in mustard yield i.e. 18.2 and 20.3% over RDF (1.69 t ha^{-1}) and 75% RDF (1.57 t ha^{-1}) alone. However, net returns indicated that INM treatment i.e. RDF + FYM + S + Zn + B + Azatobacter with mean returns of Rs. 19,505 is promising to rest of the treatments.

Hussain *et al.* (2008) reported that the effect of boron application on yield and yield attributes of different mustard varieties. The experiment involved five boron levels *viz*. 0, 0.5, 1.0, 1.5 and 2.0 kg B ha^{-1} and three mustard varieties *viz*. BARI sarisha-8, BARI sarisha -9 and BARI sarisha -11. The experiment revealed that 1.0 to 1.5 kg B ha^{-1} should be applied along with recommended fertilizers produced higher seed yield. BARI sarisha-8 and BARI sarisha -11 performed better and highly response to boron than BARI sarisha-9. Highest seed yield (1.57 t ha^{-1})

was obtained from the combination of BARI sarisha -11 and boron level 1 kg ha^{-1}

Halder ***et al. (*****2007**) reported that a field experiment was conducted to find out the optimum dose of boron and to evaluate a suitable variety for maximizing the yield of mustard. Four varieties BARI sarisha-6, BARI sarisha-7, BARI sarisha-8 and BARI sarisha-9 integrated with four levels boron (0, 1.0 1.5 and 2.0 kg ha^{-1}).

Jahiruddin ***et al. (*****2007)** stated that boron deficiency is a major reason for lower yield of wheat and mustard. This element deficiency has arisen mainly due to continuous mining soil nutrients for increased cropping intensity without adequate replenishment. Boron deficiency induces grain sterility. Again, crop species and varieties may differ in their sensitivity to boron deficiency.

Thapa (2006) conducted a field experiment with three levels of boron (0, 1 and 2 kg ha^{-1}). Oil yield of rapeseed was highly significant on boron treatment. The highest plant height (98.76cm), the higher number of siliqua plant $^{-1}$ and higher yield (288.5kg ha^{-1}) were produced from 1kg B ha^{-1}.

Miah ***et al.(*****2005**) conducted an experiment with three levels of boron increased which the number of pods set $plant^{-1}$, percentage of pod setting, plant height, number of branches $plant^{-1}$, siliqua $plant^{-1}$, seed $siliqua^{-1}$, 1000-seed weight, seed yield $plant^{-1}$, shoot weight $plant^{-1}$, seed and straw $yield^{-1}$ but had no significant effect on number of flowers.

Haque (2000) conducted a field experiment with 3 levels of boron *viz*. 0, 1 and 2 kg B ha^{-1}. He obtained the highest seed yield recorded by the treatment receiving 1kg B $ha^{-1.}$

Shen *et al.* (1993) conducted an experiment with rapeseed using 0, 0.3, 0.6 and 1.0 ppm boron. Boron application markedly increased the number of pods set, the average number of pod set, the average number seed pod^{-1}, seed yield and increased the content of soluble protein.

Wang *et al.* (1995) reported that boron deficiency or toxicity decreased in rape. Boron deficiency and toxicity increased RNA activity in leaves and anthers, decreased DNA contents and decreased in protein synthesis.

Islam and Sarkar (1993) reported that the application of boron increased significantly the number of siliqua plant^{-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.

Singh *et al.* (1991) reported that application of boron significantly increased the yield of mustard and 1.6 kg B ha^{-1} appeared to be the optimum B level for mustard and the straw yield of mustard crop increased significantly by boron application.

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

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

Yang *et al.* (1989) reported that in field and pot trials of rapeseed with B, N and K application. Boron application increased B content of all plant parts, but especially leaves. Seed yield was positively correlated with soil and especially leaf B content. Applying B, N and K promoted growth, CO_2 assimilation, nitrate reductase activity in leaves and DM accumulation. Seed glucosinolate and erucie acid contents varied among cultivars and generally decreased with increasing soil K and B while seed oil content increased. Increasing N rate had the opposite effect, combined B, N and K application increased seed yield.

Chatterjee *et al.* (1985) carried out field experiments and found that the application 20 kg S ha^{-1} through gypsum in conjunction with borax (10 kg ha^{-1}) produced a 42% increase in the seed yield of *Brassica juncea.* Borax, zinc sulphate equivalent to 20 kg S ha^{-1} and gypsum when applied alone produced 34, 26 and 39% increase in yield, respectively. Combination of these nutrient products, however, did not show any additive effect. The increase in yield was mainly due to an increase in the number of siliqua $plant^{-1}$ and 1000-seed weight.

Saini *et al*. (1985) reported that seed yield of *Brasica juncea* were increased by increasing N rates from 0 to 120 kg and S rates from 0 to 30 kg ha^{-1} and by applying 10 kg Zn and 1 kg B ha^{-1}. The response to S, Zn and B increased with increase in N rates. Yields with 30 kg S in combination with 120 kg N were 20.5% and 97.7% higher than with S in combination with 60 kg N or no N, respectively. Oil content decreased slightly with increasing N rates and increased slightly with S. Zn and B.

Thomas (1985) reported that the highest yields were achieved on medium to heavy soil with 40 kg N and 40 kg P, 80 kg K, 1kg B and 30 kg S ha^{-1} applied before sowing, plus 180 kg to 220 kg each of N ha^{-1}

applied as top dressing in two installments in late February to early March.

Dutta *et al.* 1984, stated that application of B (1 kg B ha^{-1}) increased leaf area ratio (LAR), leaf area index (LAI), crop growth rate (CGR), number of branches $plant^{-1}$, number of pods $plant^{-1}$, weight of seeds pod^{-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.

Krauze and Bobrzecka (1983) reported that application of S reduced and B increased the contents of oleic, linoleic and linolenic acids but they both increased the content of goestrogenic components and isothiocyanates of rape seed.

Yadav and Manchandra (1982) reported that increased level of boron application in mustard (*Brassica campestris*) increased tissue in B content.

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 13 levels 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 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 .

2.4. Interaction effect of irrigation, sulpur and boron on mustard

Ray *et al.* (2015) conducted field experiments on clay loam soil during winter season of 2010–2011 and 2011–2012 at the Research Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to study the influence of sulphur (S) levels and irrigation on quality and yield of mustard (cv. Varuna, T-59. Irrigation (twice at 30 DAS and60 DAS) in combination with 45 kg S ha^{-1} are recommended for improving yield attributes, yield, oil percent and S uptake of Indian mustard.

Kumer *et al.* (2013) conducted a field experiment during the two consecutive post rainy seasons (*rabi*) of 2009–2010 and 2010–2011 at Crop Research Farm, Department of Agronomy, SHIATS, Allahabad, to study the effect of Boron and Sulphur on growth and yield of chickpea under chickpea + mustard cropping system. The combinations of treatments consisted of 4 intercropping system *viz*., sole chickpea, sole mustard, chickpea + mustard 4:1 (row ratio) and chickpea + mustard 5:1(row ratio) and consisted of 6 boron and sulphur levels *viz*., control, borax 10 kg ha^{-1}, boric acid 0.25% foliar spray at 30, 45 and 60 DAS, sulphur 30 kg ha^{-1}, borax 10 kg ha^{-1} + sulphur 30 kg ha^{-1}, boric acid 0.25% foliar spray at 30, 45 and 60 DAS + sulphur 30 kg ha^{-1}. Significantly increased plant height due to intercropping of chickpea with mustard 4:1 rows ratio and no. of branches, no. of nodules and dry weight were obtained in sole chickpea than intercropping of chickpea with mustard 4:1 and 5:1 were on par. Borax 10 kg ha^{-1} + sulphur 30 kg ha^{-1} gave the significantly highest plant height, no. of branch, no. of nodules and dry weight of chickpea and mustard and it was *on par* with boric acid 0.25% trice spray + sulphur 30 kg ha^{-1} followed by different borax and sulphur levels were on par over the control.

Yeasmin *et al.* (2013) conducted that a field experiment on rapeseed a comprising of four levels of sulphur (0, 30, 35 and 40 kg S ha^{-1}) and three levels of boron (0, 1and 2 kg B ha^{-1}) was conducted at Rajshahi, Bangladesh to study the contribution of sulphur and boron in improving yield and yield components of rapeseed. The highest number of flowers plant^{-1} (159.8), number of pods plant^{-1} (133.8), and 1000-seed weight (3.27g) was obtained from the treatment combination of 30 kg S ha^{-1} with 1kg B ha^{-1}.

Nadian *et al.* (2010) conducted a field experiment to study the interactions between boron (B) and sulpher (S) on yield and yield components of canola (*Brassica napus* L.) in a calcareous soil. The experiment had a completely randomized design consisting of a 4×3 factorial combination of four B rates (0, 2.5, 5.0, 7.5 and 10.0 kg ha^{-1}) and three S rates (0, 400 and 800 kg ha^{-1}) arranged in four replications. The results showed that interaction between B and S was significant on yield of dry matter, grain yield, oil and protein yields. The highest grain yield of canola (3002.4 kg ha^{-1}) was observed when 2.5 kg B and 800 kg S ha^{-1} were applied. Interaction between B and S application led to the highest leaf B concentration at rate of 10 kg B and 800 kg S ha^{-1}.

Moniruzzaman *et al.* (2008) conducted field experiment on mustard comprising of four levels of each of sulphur (0, 10, 20 and 30 kg ha^{-1}) and boron (0, 1, 1.5 and 2 kg ha^{-1}) was conducted at the Agricutural Research Station, Rai khali, Rangamati Hill district during the rabi season of 2004-05 and 2005-2006 on the growth, yield and profitability of the crop. The fertilizer treatments had significant effects on growth and yield parameters *viz.* plant spread, numbers of leaves plant^{-1}, head diameter, main head weight and weight of secondary shoot plant^{-1}. The interaction effect of sulphur and boron showed significant effect on seed yield. 20 kg ha^{-1} sulphur with 1.5 kg ha^{-1} boron produced the highest seed yield.

Karthikeyan *et al.* (2008) conducted a greenhouse experiment with a soil (Typic Haplustalf) deficient in boron and sulphur to study the effect of interaction between B and S on their uptake and quality parameters of mustard (*Brassica juncea* L.). The interaction effect between boron and sulphur significantly and synergistically influenced the dry matter and seed yields of both the crops, which were observed the highest at 60 mg kg^{-1} of S in conjunction with 2 mg kg^{-1} of boron. The oil and protein contents of mustard were significantly and synergistically improved by the application of both sulphur and boron.

Thapa (2006) carried out an experiment at Gunjanagar, Chitwan, Nepal with three levels of boron (0, 1, 2 kg ha^{-1}) and four levels of sulphur (0, 20, 40, 60 kg ha^{-1}). He obtained the highest seed yield (1034 kg ha^{-1}) from the combination of 1 B kg ha^{-1} with 40 kg S ha^{-1} which was significantly differed from without B and S. The interaction effects of B and S on number of $siliqua^{-1}$ was not significant.

Haque (2000) carried out an experiment at BAU farm, Mymensigh, with *Brassica nupus* L. where 0, 15, 30 and 45 kg S ha^{-1} were used. The interaction effect of S and B showed significant effect on number of pods $plant^{-1}$ and seed yield. Application of 30 kg S ha^{-1} with 1 kg B ha^{-1} gave highest yield.

The present study was under taken to find out a suitable level of irrigation, sulphur and boron for maximizing seed yield and oil content of mastard.

Chapter 3

MATERIALS AND METHODS

The study was conducted at the Agronomy Field Laboratory, department of Agronomy and Agricultural extension, Rajshahi during the period from October 2012 to February 2013 and October 2013 to February 2014 to investigate the effect of different levels of irrigation, sulpher and boron on the growth, yield and quality of mustard.

The materials and methods used in performing this experiment are described in this chapter. This chapter for convenience, has been divided into various sub-heads such as location, experimental site and soil, climate, crop variety, design of the experiment, treatments, land preparation, application of fertilizers, seed treatment, sowing of seed, weeding and thinning, irrigation, insect control, harvesting and threshing, collection of experimental data, observation and methods of the data collection and statistical analysis and chemical analysis are given below:

3.1. Description of experimental site

3.1.1. Location

The field belongs to the high Ganges River Flood plain soil of AEZ-11. The soil was sandy loam with p^H 8.5. The experimental field is geographically located at $24°22^{/}36^{//}$ N Latitude $88°\ 38^{/}27^{//}$ E Longitude at an average altitude of 71ft above sea level.

3.1.2. Soil

The experimental plot of the department of Agronomy and Agricultural Extension of Rajshahi University, Rajshahi is of poorly drained soil with moderately slow permeability. The top soil is silty loam and slightly alkaline in reaction. The chemical characteristics of experimental soil have been presented in Appendix I-II-III.

3.1.3. Climate

Mustard is a cool season crop that can be grown in a short growing season. The crop was grown in the winter season when the day length (sunshine period) was reduced and there was unexpected rainfall at the beginning of the experiment and also at the time of harvesting .The monthly average temperature, humidity, rainfall and plenty of sunshine hours prevailed at the experimental area during the period of study (November 2012-2013 to February 2013-2014). The monthly average, maximum and minimum air temperature, relative humidity and sunshine hours of the experimental area during the experimental period are given in Appendix IV-V.

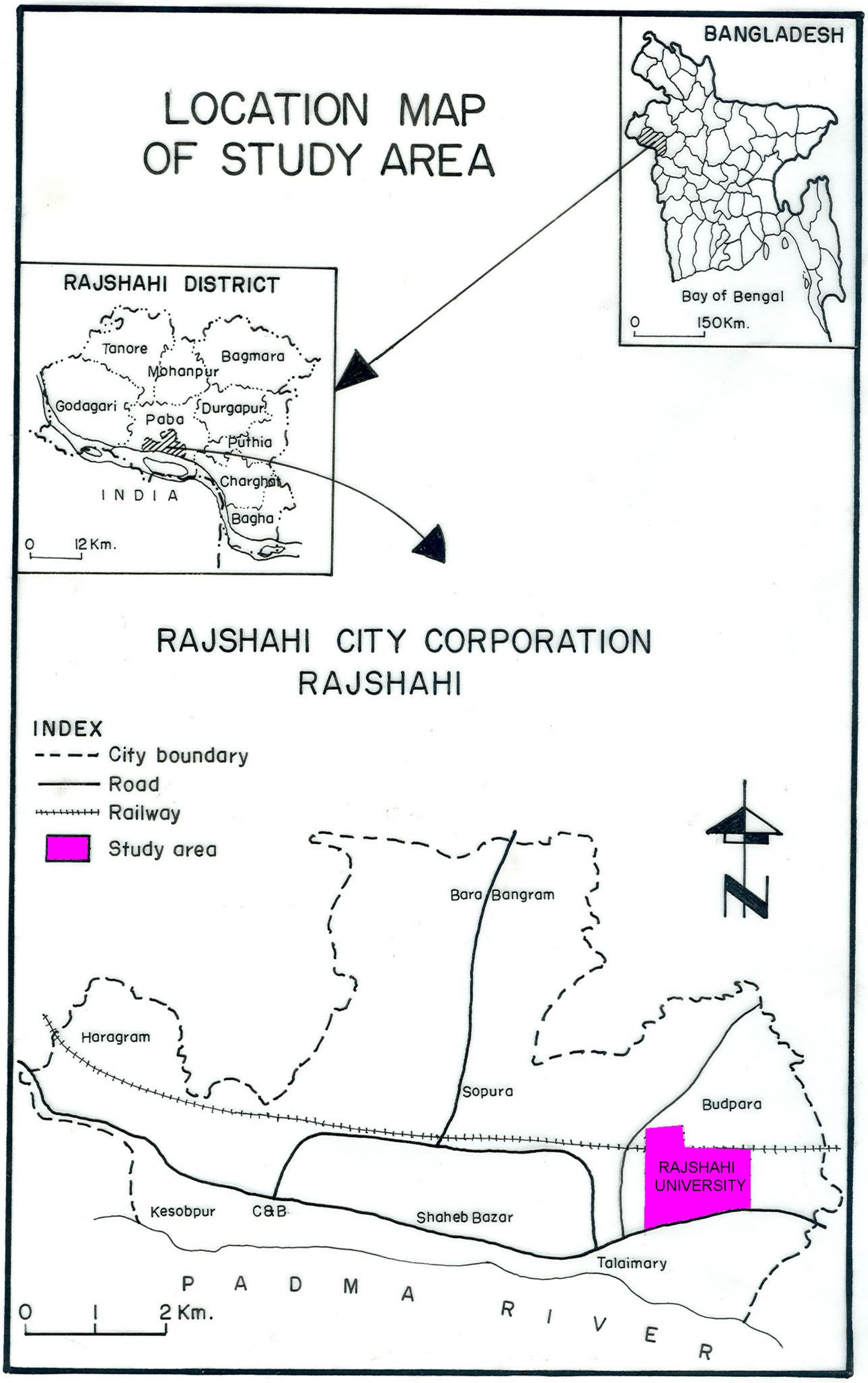


Plate 1. Location of Study Area

3.2. Crop variety

The crop under study was mustard and the variety was BARI sarisha-16. The variety has been developed by the scientists of Bangladesh Agricultural Research Institute (BARI), joydebpur Gazipur. This particular variety has gained popularity among the farmers of Bangladesh for its high yield potential. Plant height is 175-195cm with 8-10 primary branches $plant^{-1}$. The siliqua was two chambered with 9-11 seeds in each. The seeds are purple in color. Thousand seed weight are 4.7- 4.9g. Total growth duration is 105-115days. The average yield is 2-2.5 t ha^{-1}. The seed was collected from Bangladesh Agricultural Development Corporation (BADC).

3.3. Treatments

The experiment was designed with three factors.

Factor-A: Levels of irrigation

i. Control irrigation = I_0

ii. One irrigation = I_1 at flowering stage

iii. Two irrigation = I_2 at siliqua development stage

Factor-B: Levels of sulphur

i. 0 kg S ha^{-1} = S_0

ii. 30 kg S ha^{-1} = S_1

iii. 40 kg S ha^{-1} = S_2

iv. 50 kg S ha^{-1} = S_3

Factor C: Levels of boron

i. 0 Kg B ha^{-1} = B_0
ii. 1 Kg B ha^{-1} = B_1
iii. 1.5 Kg B ha^{-1} = B_2
iv. 2 Kg B ha^{-1} = B_3

3.4. Design of the experiment

The experiment was laid out in a split- split- plot with 3 replications. Experimental area was divided into three main plots which irrigation was applied and then each main plot was further divided into four sub plots and sulpher were allocated to these plots. Each sub- plots was again divided into four sub-sub-plots and boron treatments were assigned in these plots. Thus, total number of plots were 144 (3×48).The size of each plot was 2m×2m.

3.5. Land Preparation

The Land of experimental plot was opened with a power tiller, later on it was ploughed and cross ploughed 2 times by country plough followed by laddering to obtain a good tilth condition. The visible larger colds were broken into small pieces by wooden hammer. Weed and stubbles were removed from the field. The land was prepared smoothly with spade before sowing of mustard. The soil was comparatively loose having no clods at all. Some weeds and crop residues were removed through picking. Thus the soil was prepared easily. The layout of the experiment was done in accordance with design adopted. In the first year, the land of experimental plot was opened on 25 October 2012 and it was ready for sowing on 4 November 2012 and in second year, the land of experimental plot was opened on 27 October 2013 and it was ready for sowing on 10 November 2013.

3.6. Application of fertilizers

Sulphur and boron were applied in the form of gypsum and borax as basal dose at final land preparation as per experimental treatments. Other fertilizers like NPK were applied at the rate of 120, 70 and 40 kg ha^{-1} from the sources of urea, TSP, and MOP, respectively. Urea was applied in three splits, 1/3 as basal, 1/3 at 28 DAS and the rest at 50% flowering.

3.7. Seed treatment

Seeds were treated with garlic crude extract. At first seeds were soaked in garlic extract for 30 minutes. Then the excess liquid was drained off and the seeds were dried in the sunlight and then sown in the field.

3.8. Sowing of seeds

In first year, the seeds were sown on 6 November 2012 and in second year 12 November 2013. Seeds were sown in lines of 30 cm apart rows opened by specially made an iron hand tine. After sowing the seeds were covered with soil and slightly pressed by hands. Seed rate was applied at the rate of 8 kg ha^{-1}.

3.9. Intercultural operations

3.9.1. Weeding and thinning

The crop was infested with some local weeds such as Bathua (*Chenopodium album*), Mutha (*Cyperus rotundus*) and Durba (*Cynodon dactylon*) etc. Two weedings and thinning were done, one at 15 DAS and the second at 30 DAS to maintain a uniform plant population in each plot.

3.9.2. Irrigation

Irrigations were applied as per treatment.

3.9.3. Insect control

Plant protection measures like spraying of Dimecron 100 EC at the rate of 2.0 ml L^{-1} against aphid (*Lipaphis erysimi*) during siliqua tilling were taken.

3.10. Soil sample collection

Soil samples from each plot were collected for chemical analysis before sowing. The samples were then composited to make a bulk sample was sieved to remove unwanted materials. These samples were air dried and then preserved in poly bags for future laboratory analysis.

3.11. Plant sample collection

From each plot seven rows of crop were used for collecting data on growth and phonological parameters. Growth study was stared from 20 days after sowing (DAS) and continued upto 80 DAS at 20 days interval. Five plants per plot carefully uprooted randomly at each time. Each plant sample was separated into leaf, stem and siliqua (when appeared). Number of leaves and number of branches were then counted. The samples were packed separately in labeled brown paper bags and were oven dried for 72 hours at 70-80^0 C. Dry weights were then measured separately with an electrical balance. At each time, leaves from those plants were collected. The leaf area of the each collected leaves was measured by disc method. For leaf area determination, five leaf segments if 4 cm lengths were taken and weighed after oven drying and leaf area was calculated by using the following formula:

$$\text{Area of leaf} = \frac{\text{Area of segments} \times \text{Weight of leaf}}{\text{Weight of Segments}}$$

3.12. Harvesting

The crop was harvested at the 90% of the siliqua maturity on February 17, 2013 and February 24, 2014. Before harvesting the whole plot, 10 plants were randomly selected from each plot for collecting data on yield attributes. After sampling, the crop from each unit plot ($4m^2$), $1m^2$ areas was selected to count the grain and straw yield. The harvested crop was bundled separately, tagged properly and taken to the clean threshing floor in both the years.

3.13. Post harvest operation

After harvesting, crop of each plot was dried separately for four days. After that harvesting, cleaning and drying of grains were done plot-wise. Then the yields of grain and straw of each plot were recorded and the yields were then converted to hectare basis.

3.14. Growth analysis technique

Different growth parameters such as CGR, LAI and NAR were calculated by following the standard formulae as shown below (Radford 1967).

1. Crop growth rate (CGR) = $\frac{W_2 - W_1}{T_2 - T_1}$

2. Leaf area index(LAI) = $\frac{\text{Leaf area}}{\text{Ground area}}$

3. Net assimilation rate (NAR) = $\frac{(W_2 - W_1) \text{ Loge } LA_2 - \text{Loge } LA_1)}{(LA_2 - LA_1)\ (T_2 - T_1)}$

W_2 and W_1 are the total dry weights;

LA_2 and LA_1 are the total leaf area per plant at t_2 and t_1 at the later and the former harvest respectively.

3.15 . Collection of experimental data

3.15.1. Plant characters in phonological stages

a. Plant height at 20, 40, 60, 80 and 100 DAS

b. Number of leaves 20, 40, 60 and 80 DAS

3.15.2. Growth parameters

a. Total dry matter (TDM) at 20, 40, 60 and 80 DAS

b. Crop growth rate (CGR) at 20-40, 40-60 and 60-80 DAS

c. Leaf area index (LAI) at 20, 40, 60 and 80 DAS

d. Net assimilation rate (NAR) at 20-40, 40-60 and 60-80 DAS

3.15.3. Yield and yield components parameters

i. Number of branches
ii. Number of siliqua plant^{-1}
iii. Siliqua length (cm)
iv. No. of seeds siliqua^{-1}
v. No. of normal seeds siliqua^{-1}
vi. No. of deformed seeds siliqua^{-1}

vii. 1000- seed weight (g)
viii. Seed yield (t ha^{-1})
ix. Straw yield (t ha^{-1})
x. Biological yield (t ha^{-1})
xi. Harvest index (%)

3.15.4. Quality parameters

xii. Moisture content (%)
xiii. Oil content (%)
xiv. Protein content (%)
xv. Carbohydrate content (%)

3.16. Observation and methods for data collection

For the convenience of collecting data, ten sample plants selected randomly in each plot. The sample plants were uprooted prior to harvest and dried properly in the sun and collected data from these plants. The seed and straw yield $plot^{-1}$ were measured from the plot area after harvesting, cleaning and drying the plants from the whole plot.

The procedures followed to determine the characters have been given below:-

1) **Plant height (cm):** The plant height was taken from ten randomly selected plants of each plot. The height of the plant was measured from the base of the plant to the tip of the upper most main stem.

2) **Number of branches:** $Plant^{-1}$ the number of branches was counted at harvest.

3) **No. of siliqua $plant^{-1}$:** The number of siliqua was counted at the siliqua setting period.

4) **Siliqua lenght (cm):** lenght of the siliqua was measured from neck node to apex of the siliqua.

5) **No. of seeds sliqua^{-1}:** Seeds were collected by splitting ten siliqua out of ten plants and then counted.

6) **No. of normal seeds siliqua^{-1}:** The number of normal seeds was counted from siliqua.

7) **No. of deformed seeds siliqua^{-1}:** The number of deformed seeds were separated and counted from siliqua.

8) **1000-seed weight:** From the seed stock of each plot 1000 seeds were randomly collected and weight was taken by an electric balance. The 1000-seed weight was recorded in gram (g).

9) **Seed yield (t ha^{-1})**: After threshing, cleaning and drying, total seed yield from the each treated plot including the one meter square was recorded as seed yield which was converted to ton ha^{-1}.

10) **Straw yield (t ha^{-1}):** After separation of seeds from plants, the straw per plot was dried separately and recorded the weight.

11) **Biological yield (t ha^{-1}):** The summation of grain yield and straw yield was considered as biological yield.

12) **Harvest index (%):** Harvest index is the relationship between grain yield and biological yield. It was calculated by using the following formula;

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

3.17. Determination of Moisture

Moisture content was determined by the conventional procedure.

Materials:

a) Porcelain crucible
b) Electrical balance
c) Oven
d) Desiccator

Procedure

About 5 gm of each of three stages of mustard seeds were weighed in a porcelain crucible (which was previously cleaned, heated to 100°C, cooled and weighed). The crucible with the sample was heated in an electrical oven for about six hours at 100°C. It was then cooled in desiccators and weighed again.

Calculation

Percent of moisture content (gm per 100 gm of mustard seed)

$$= \frac{\text{Weight of ash obtained}}{\text{Weight of the sample}} \times 100$$

2.2.6. Determination of lipid

Lipid content of the mustard seed was determined by the method.[26]

Reagent

Mixture of chloroform and ethanol (2: 1 V/V).

Procedure

About 5 gm of dry mature and ripen mustard seeds were first pasted in a mortar with about 10 ml of distilled water. The pasted flesh was transferred to a separating funnel and 30 ml of chloroform-ethanol mixture was added and mixed well. It was then kept overnight at room temperature in the dark. At the end of this period, 20 ml of chloroform and 20 ml of water were further added and mixed. Three layers were seen. A clear lower layer of chloroform containing the entire lipid, a colored aqueous layer of ethanol with all water-soluble materials and a thick pasty inter-phase were seen.

The chloroform layer was carefully collected in a pre-weighed beaker (50 ml) and then placed on a steam bath for evaporation. After evaporation of the chloroform, the weight of the beaker was determined again. The difference in weight gives the amount of the lipid.

Calculation

Percent of lipid content (gm per 100 gm of mustard seed)

$$= \frac{\text{Weight of lipid obtained}}{\text{Weight of sample taken}} \times 100$$

3.18. Determination of Total Protein

Total protein contents of mustard seed was determined by the micro-kjeldahl method (Ranganna, 1986)[61].

Apparatus Required

a) Kjeldahl digestion flask: 250 ml capacity.
b) Distillation apparatus.
c) 100 ml conical flask.
d) 50 ml beaker.
e) 50 ml burette.
f) 100 ml volumetric flask.

Reagents Required

a) **Mixed indicator:** Prepared 0.1% bromocresol green and 0.1% methyl red indicators in 95% alcohol separately. 10 ml of the bromocresol green was mixed with 2 ml of the methyl red solution in a bottle provided with a dropper, which delivered about 0.05 ml per 4 drops.

b) **2% Boric acid:** 10 g of boric acid (crystals) was dissolved in 500 ml of boiling distilled water. After cooling, the solution was transferred into a glass-stoppered bottle.

c) **30% Sodium hydroxide solution:** 150 g of sodium hydroxide pellets was dissolved in 375 ml of distilled water. The solution was stored in a bottle closed with rubber stopper.

d) **Catalysts for digestion:** 2.5 g of powdered selenium dioxide (SeO_2), 100 g of potassium sulphate (K_2SO_4), and 20 g of copper sulphate ($CuSO_4$, $5H_2O$) were mixed.

e) **0.01 N Hydrochloric acids:** The concentration of the solution was checked against pure sodium carbonate.

f) Procedure

Digestion

The sample was weighed accurately and transferred to a 250 ml Kjeldahl flask. 1 g of catalyst mixture and 25 ml of conc. H_2SO_4 were added to it. The flask was placed in an inclined position on the stand in the digestion chamber. The flask was heated gently over a low flame until the initial frothing was ceased and the mixture was boiled briskly at a moderate rate. During heating the flask was rotated several times. The heating was continued until the color of the digest was pale blue. The digest was cooled and 30 ml of water was added to 5 ml portion with mixing. The digest was transferred to a 100 ml volumetric flask. The flask was then rinsed 2 or 3 times with water and the washings were transferred to the volumetric flask. The solution was made up to volume with water. A blank digestion was carried out without the sample and the digest was made up to 100 ml in total.

Distillation and Titration

The distillation apparatus was set up as a flask was placed under the condenser. The distilled water was boiled in the steam generator using a Bunsen burner. Stopcock and pinck clamp were closed. Cold water was run through the condenser, from which about 5 ml of distillate was collected per minute. The burner was removed; where upon the condensate in the distilling flask was sucked back into the steam trap. Funnel was filled with distilled water, and the stopcock was opened momentarily to drain the water into flask.

The burner was then replaced under the steam generator for about 20 seconds and it was removed again. 20 ml of 2% boric acid was pipetted into a clean conical flask and the mixed indicator was added to it. The micro burette was filled with 0.01 N HCI to the zero mark by this time; the distilling flask had become empty. The burner was replaced under the steam generator and pinch clamp was opened to remove liquid from the steam trap. The pinch clamp was left on the glass tubing through which the steam was escaped. The beaker was replaced under the condenser with the conical flask containing boric acid, and the flask was supported in an oblique position, so that the tip of the condenser was completely immersed into the liquid. The stopcock was opened with one hand and with the other hand 10 ml of the digest was pipetted into. The funnel was rinsed twice with about 2 to 3 ml portions of distilled water. Then necessary amount of 30% NaOH was introduced and stopcock was closed. The pinck cock was replaced on the digestion mixture and sodium hydroxide, and the ammonia was liberated which escaped with steam through the condenser into the boric acid solution.

The boric acid was changed from bluish purple to bluish green as soon as it came in contact with ammonia. The change, which was very sharp, was taken place between 20 to 30 seconds after the pinch clamp was closed. Boric acid had changed color within 5 minutes; the conical flask was lowered sot that the condenser tip was 1 cm above the liquid. The end of the condenser was washed with a little distilled water. Distillation was continued until sufficient distillate was collected. The burner was then removed. The distillate was titrated with standard hydrochloric acid until the blue color was disappeared. The titrated was done in daylight. The blank distillation and titration were carried out as in the case of the sample. The percentage of protein in sample was calculated using the following formula:

$$\text{Percentage of nitrogen} = \frac{(V_A - V_B) \times N \times 14 \times V_M \times 100}{A \times W \times 100}$$

Where,

W = Weight of the sample taken

V_A = Volume of HCI in actual titration

V_B = Volume of HCI in blank titration

N = Normality of HCI

V_M = Volume made up of the digest

A = Aliquot of the digest taken

Thus, % Protein = % Nitrogen × 6.25

3.19. Determination of carbohydrate content of mustard seed

The starch content of the mustard seed was determined by the Anthrone method as described in Laboratory Manual in Biochemistry.[25]

Reagents

(a) Anthrone reagent (0.2% anthrone in conc. H_2SO_4),

(b) Standard glucose solution (10 ml/100 ml)

(c) 1M HCl

Procedure

About 5 gm of mustard seed were cut into small pieces and homogenized well with 20 ml of water. The homogenate was then filtered through double layer of muslin cloth. To the filtrate, twice the volume of ethanol was added to precipitate the polysaccharide, mainly starch. Then it was kept overnight in cold; the precipitate was collected by centrifugation at

3,000 rpm for 15 minutes. The precipitate was then dried over a steam bath. Then 40 ml of 1M HCl acid was added to the dried precipitate and heated to about 70°C. It was transferred to a volumetric flask and diluted to 100 ml with 1M HCl. Then 2 ml of diluted solution was taken in another 100 ml volumetric flask and made up to the mark with 1M HCl.

An aliquot of 1 ml of the extract was pipette into test tubes and 4 ml of anthrone reagent was added to the solution of each tube and mixed well. Glass marbles were placed on top of each tube to prevent loss of water by evaporation. The tubes were placed in a boiling water bath for 10 minutes, then removed and cooled. A reagent blank was prepared by taking 1 ml of anthrone reagent in a test tube and treated as before. The absorbance of the blue-green solution was measured at 680 nm in a colorimeter. The amount of starch present in the mustard seed was calculated from standard curve of glucose (figure 2.2).

Calculation

The percent of carbohydrate (gm per 100 gm of mustard seed)

$$= \frac{\text{Weight of starch obtained}}{\text{Weight of the sample}} \times 100$$

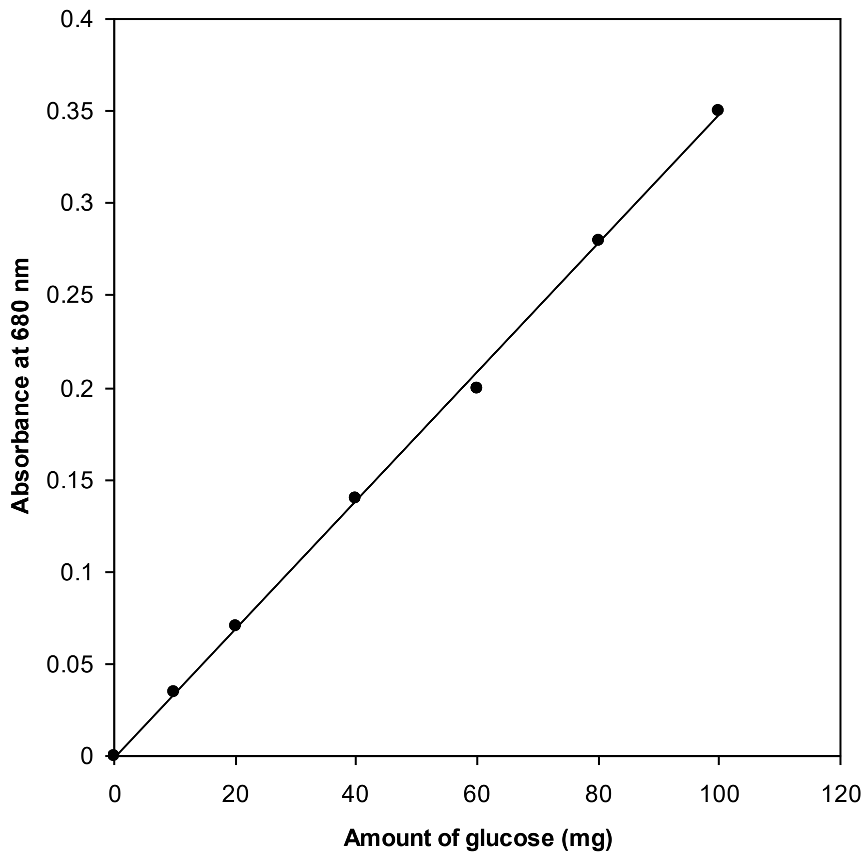


Figure 2.2. Standard curve of glucose for estimation of total soluble sugar and carbohydrate.

3.20. Statistical analysis

Data recorded were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done with the help of computer package MSTAT-C. The mean differences were compared with Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Plate 2. Germination stages

Plate 3. Vegetative stages

Plate 4. Flowering stage

Plate 5. Siliqua formation stage

Plate 6. Ripping stage

Plate 7. Determination oil content (%)

Plate 8. Determination of carbohydrate content (%)

Plate 9. Determination of protein content (%)

Chapter 4

RESULTS

This chapter presents the results of the experiment regarding growth, phonological characters, yield and quality of mustard as influenced by sulpher, boron and irrigation. The detailed experimental results have been presented in this chapter as given below:

4.1. Phenological characters

Study of Phenological characters i.e. plant height and number of leaves in the growth period of mustard plant as affected by irrigation, sulpher and boron levels and their interaction.

4.1.1. Plant height

Different irrigation, sulpher and boron levels had statistically significant effect on plant height at different days after sowing (DAS) except 20 DAS.

The highest plant height was observed when field was received two irrigations at 40, 60, 80 and 100 DAS which was statistically similar to one irrigation in both the years. The lowest plant height was found in no irrigation (control) in both the years (Table 1).

The result revealed that the highest plant height was found when 40 kg S ha^{-1} was applied to the mustard field which was statistically similar to 50 kg S ha^{-1} and the lowest results were found in control at 40, 60 and 80 DAS in both the years. At 100 DAS, the highest plant height was recorded in S_3 treatment which was statistically similar to S_1 and S_2

treatments and the lowest plant height was observed in control in both the years (Table 2).

The tallest plants were produced in the plots where applied 1.5 kg B ha^{-1} which was statistically similar to the dose of 2 kg B ha^{-1} and 1 kg B ha^{-1} and dwarf plants were observed in the field where no fertilizer was used at 40, 60, 80 and 100 DAS in both the years (Table 3).

The interactions between irrigation and sulpher levels had significant effect on plant at different days after sowing 40 and 80 DAS in both the years. Interactions between two irrigations with 40 kg S ha^{-1} (I_2S_2) gave the highest plant height at 40 and 80 DAS in both the years and lowest value was obtained in I_0S_0 treatment combination (Table 4).

The interaction between different levels of irrigation and boron levels had shown significant effect on plant height at 40, 60 and 80 DAS except 20 DAS. At 40 DAS in both trails, the highest plant height was obtained from the interaction of I_2B_2 which was statistically similar to I_1B_1, I_1B_2, I_1B_3, I_2B_1 and I_2B_3 treatment combinations. At 60 DAS, the highest plant height was observed from the interaction of I_2B_2 which was statistically similar to I_1B_2, I_1B_3, I_2B_1 and I_2B_3 treatment combinations in 2012-2013 and in 2013-2014, the highest plant height was observed from the interaction of I_2B_2 which was statistically similar to I_1B_1, I_1B_2, I_1B_3, I_2B_1 and I_2B_3 treatment combinations. At 80 DAS in both trails, the interaction of I_2B_2 gave the highest plant height which was statistically identical to I_2B_1 and I_2B_3 treatment combinations. The lowest plant height was obtained from the interaction of B_0I_0 i.e. 0 kg B ha^{-1} with no irrigation treatment combination (Table 5).

The interaction between the different levels of sulpher and boron fertilizer had shown statistically significant effect on plant height at sampling dates of 40 and 80 DAS in both the years. At 40 DAS, the highest plant height was obtained from S_2B_2 treatment combination in both the years. At 80 DAS in 2012-2013 and 2013-2014, the highest plant was found from S_2B_2 treatment combination which was statistically similar to S_2B_1, S_2B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations. The lowest plant height was observed from control levels of sulpher with control level of boron (Table 6).

Table 1. Effect of irrigation on plant height (cm) at different days after sowing (DAS)

Irrigation	2012-2013					2013-2014				
	Plant height					Plant height				
	20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
I_0	5.596	18.969b	82.423b	136.465b	154.690b	5.416	18.221b	78.802b	132.353b	160.074b
I_1	5.404	26.478a	91.454ab	149.804a	162.627a	5.367	25.895ab	87.683ab	145.690a	168.555a
I_2	5.406	28.140a	96.197a	155.853a	168.951a	5.407	27.503a	92.403a	151.471a	171.971a
LS	NS	0.01	0.01	0.01	0.05	NS	0.01	0.01	0.01	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant I_0 = Control
LS=level of significant I_1 = One irrigation
I_2 = Two irrigations

Table 2. Effect of sulpher on plant height (cm) at different days after sowing (DAS)

Sulpher	2012-2013					2013-2014				
	Plant height					Plant height				
	20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
S_0	5.399	13.514c	71.832b	122.954c	144.430b	5.192	13.166c	68.561b	119.264c	149.344b
S_1	5.500	23.681b	92.417a	148.424b	164.625a	5.480	23.189b	88.608a	144.009b	170.510a
S_2	5.465	32.872a	99.811a	161.256a	168.661a	5.282	32.094a	95.820a	157.055a	174.886a
S_3	5.511	27.685ab	96.039a	156.862a	170.641a	5.633	27.044a	91.195a	152.357a	176.726a
LS	NS	0.01	0.01	0.05	0.01	NS	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant $S_0 = 0$ kg S ha^{-1}
LS=level of significant $S_1 = 30$ kg S ha^{-1}
$S_2 = 40$ kg S ha^{-1}
$S_3 = 50$ kg S ha^{-1}

Table 3. Effect of boron on plant height (cm) at different days after sowing (DAS)

Boron	2012-2013					2013-2014				
	Plant height					Plant height				
	20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
B_0	5.461	15.900b	76.882b	130.173b	149.029b	5.045	15.503b	73.553b	126.406b	154.082b
B_1	5.431	26.953a	91.703a	152.197a	167.385a	5.379	26.335a	87.874a	147.927a	173.354a
B_2	5.353	28.540a	96.977a	154.668a	168.876a	5.561	27.897a	93.065a	150.204a	174.935a
B_3	5.631	26.358a	94.536a	152.457a	163.068a	5.601	25.758a	90.692a	148.148a	169.096a
LS	NS	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant B_0= 0 kg B ha^{-1}
LS=level of significant B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 4. Interaction effect of irrigation and sulpher on plant height (cm) at different days after sowing (DAS)

Interaction (I×S)	2012-2013					2014-2015				
	Plant height					Plant height				
	20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
$I_0 S_0$	5.567	12.717g	67.167	118.375f	139.207	5.215	12.432f	63.952	114.757g	143.875
$I_0 S_1$	5.596	18.575fg	83.758	138.188de	156.662	5.243	18.044ef	80.025	133.954f	162.158
$I_0 S_2$	5.313	22.150ef	89.633	145.313cd	161.912	5.401	21.594de	85.855	140.993ef	167.658
$I_0 S_3$	5.908	21.342ef	89.133	143.983cd	160.980	5.807	20.816de	85.377	139.707ef	166.602
$I_1 S_0$	5.463	14.175g	74.179	124.921ef	145.935	5.214	13.779f	70.865	121.176g	150.942
$I_1 S_1$	5.396	26.908cde	95.396	151.300bcd	166.905	5.398	24.999cd	91.557	146.813de	172.925
$I_1 S_2$	5.608	37.133ab	98.487	161.138abc	163.620	5.243	36.407ab	94.404	157.464bc	170.092
$I_1 S_3$	5.158	32.142bc	97.783	161.212abc	174.048	5.773	28.887c	93.903	156.622bc	180.262
$I_2 S_0$	5.167	13.650g	74.150	125.566ef	148.149	5.146	13.288f	70.866	121.860g	153.217
$I_2 S_1$	5.508	25.558de	98.096	155.783bcd	170.310	5.642	26.239cd	94.242	151.259cd	176.446
$I_2 S_2$	5.475	39.333a	111.312	177.317a	180.452	5.360	38.566a	107.202	172.707a	186.908
$I_2 S_3$	5.467	29.571cd	101.200	165.391ab	176.895	5.319	31.428bc	97.304	160.743b	183.313
LS	NS	0.01	NS	0.05	NS	NS	0.01	NS	0.05	NS

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NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 5. Interaction effect of irrigation and boron on plant height (cm) at different days after sowing (DAS)

Interaction (I×B)	2012-2013					2013-2014				
	Plant height					Plant height				
	20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
I_0 B_0	5.100	15.625b	74.708e	128.204c	147.099	4.978	15.303b	71.458e	124.587c	151.887
I_0 B_1	5.475	19.950b	85.700bc	139.613bc	157.265	5.423	19.442b	81.962bc	135.371bc	162.829
I_0 B_2	5.013	20.392b	86.500bc	140.775bc	158.288	5.436	19.839b	82.748bc	136.435bc	163.888
I_0 B_3	5.337	18.817b	82.783cd	137.267bc	156.108	5.829	18.302b	79.040cd	133.017bc	161.692
I_1 B_0	5.375	16.033b	78.225de	130.812c	149.560	4.981	15.593b	74.82de	126.940c	154.683
I_1 B_1	5-550	29.058a	89.233b	154.308ab	170.506	5.419	28.407a	83.384b	150.218ab	176.683
I_1 B_2	5.729	30.789a	100.087a	157.471ab	172.391	5.594	30.129a	98.136a	153.108ab	178.608
I_1 B_3	5.717	30.017a	98.783a	155.933ab	158.050	5.635	29.540a	96.101a	151.743ab	164.246
I_2 B_0	4.808	16.042b	77.713de	131.503c	150.428	5.178	15.612b	74.348de	127.691c	155.675
I_2 B_1	5.800	30.850a	100.175a	162.671a	174.384	5.296	31.155a	96.279a	158.192a	180.550
I_2 B_2	5.883	34.433a	104.345a	165.758a	174.384	5.653	33.724a	100.347a	161.069a	182.308
I_2 B_3	5.837	31.242a	102.042a	164.170a	175.948	5.340	29.433a	94.899a	159.684a	181.350
LS	NS	0.01	0.05	0.01	NS	NS	0.01	0.05	0.01	NS

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NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 6. Interaction effect of sulpher and boron on plant height (cm) at different days after sowing (DAS)

Interaction (S×B)	2012-2013					2013-2014				
	Plant height					Plant height				
	20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
$S_0 B_0$	4.922	12.556f	65.406	119.949c	136.421	4.650	12.294f	62.332	116.670c	140.978
$S_0 B_1$	5.122	13.500f	73.233	123.294c	146.503	5.575	13.134f	69.903	119.509c	151.522
$S_0 B_2$	5.650	14.167f	74.733	124.594c	147.712	5.332	13.780f	71.389	120.688c	152.756
$S_0 B_3$	5.600	13.833f	73.956	123.978c	147.086	5.209	13.457f	70.619	120.190c	152.122
$S_1 B_0$	5.400	15.067f	77.856	130.444c	150.249	5.260	14.641f	74.462	126.563c	155.444
$S_1 B_1$	5.350	26.022de	96.500	152.756ab	168.160	5.936	25.361de	92.563	148.172ab	174.250
$S_1 B_2$	5.461	27.111d	98.100	156.011ab	169.971	5.431	26.420d	94.149	151.409ab	176.111
$S_1 B_3$	5.789	26.522de	97.211	154.483ab	170.121	5.295	25.955de	93.258	149.891ab	176.233
$S_2 B_0$	5.667	17.100f	80.956	132.000c	152.608	5.266	16.642f	77.522	128.017c	157.933
$S_2 B_1$	5.350	37.433ab	97.444	169.039a	179.077	4.899	36.688ab	93.376	165.017a	185.478
$S_2 B_2$	5.344	40.856a	111.176	172.911a	181.047	5.291	40.076a	106.819	168.268a	187.644
$S_2 B_3$	5.500	36.100abc	109.667	171.072a	161.913	5.672	35.350abc	105.564	166.917a	168.489
$S_3 B_0$	5.856	18.878ef	83.311	138.300bc	156.838	5.005	18.432ef	79.894	134.374bc	161.972
$S_3 B_1$	5.9 00	30.856bcd	99.633	163.700a	175.800	5.107	30.156bcd	95.656	159.010a	182.167
$S_3 B_2$	4.956	32.028bcd	103.900	165.156a	176.774	6.189	31.314bcd	99.905	160.450a	183.228
$S_3 B_3$	5.333	28.978cd	97.311	160.293a	173.152	6.230	28.272cd	93.325	155.596a	179.539
LS	NS	0.01	NS	0.01	NS	NS	0.01	NS	0.01	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

4.1.2. Number of leaves

Different levels of had significant irrigation, sulpher and boron doses had significant effect on number of leaves at 40, 60 and 80 DAS except 20 DAS in both the years.

At 40, 60 and 80 DAS in both the years, I_1 treatment produced the highest number of leaves. This result was statistically similar to I_2 treatment at 60 DAS in 2012-2013 and 80 DAS in both trails. The lowest value was found in I_0 treatment (Table 7).

At 40 DAS in both the years, the highest number of leaves was found in S_2 treatment. This result was statistically similar to S_1 and S_3 treatments in 2013-2014. At 60 DAS in both the years, the highest number of leaves was obtained in S_2 treatment. This result was statistically similar to S_1 and S_3 treatment in 2012-2013. At 80 DAS, the highest number of leaves was found in S_2 treatment which was statistically similar to S_1 and S_3 treatment in 2012-2013 and 2013-2014. The lowest value was obtained in S_0 treatment (Table 8).

At 40, 60, and 80 DAS, the highest number of leaves was obtained from B_2 treatment which was statistically similar to B_1 and B_3 treatments and the lowest number of leaves was obtained from B_0 treatment in both the years (Table 9).

The interaction between irrigation and sulpher levels had significant effect on number of leaves at 80 DAS in both the years. At 80 DAS (2012-2013 and 2013-2014), the maximum number of leaves was produced by the I_1S_2 treatment combination. The minimum number of leaves was observed in the control treatment combination (Table 10).

7Interaction of irrigation and sulpher levels had significant effect on number of leaves at 60 and 80 DAS in both trails. At 60 DAS in both trails, the maximum number of leaves was found in the I_1B_2 treatment combination which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combinations. At 80 DAS in both trails, the maximum number of leaves was observed in the I_1B_2 treatment combination and control treatment combination gave the minimum number of leaves (Table 11).

Interaction of sulpher and boron levels significantly influenced on number of leaves at data sampling dates such as 60 and 80 DAS in both the years. At 60 and 80 DAS in the both years, the highest number of leaves was observed in the S_2B_2 treatment combination and control treatment combination produced the lowest number of leaves (Table 12).

Table 7. Effect of irrigation on number of leaves at different days after sowing (DAS)

Irrigation	2012-2013				2013-2014			
	Number of leaves				Number of leaves			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0	5.470	12.672b	20.429b	14.802b	5.204	12.198b	19.308b	13.948b
I_1	5.461	14.132a	24.870a	17.349a	5.190	13.495a	23.587a	16.333a
I_2	5.422	13.792ab	23.695ab	16.648a	5.149	13.209ab	22.464a	15.685a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

Table 8. Effect of sulpher on number of leaves at different days after sowing (DAS)

Sulpher	2012-2013				2013-2014			
	Number of leaves				Number of leaves			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
S_0	5.244	11.873c	17.618b	11.807b	4.981	11.526b	16.624b	11.080b
S_1	5.534	13.587b	23.330a	17.041a	5.269	13.001a	22.773ab	16.074a
S_2	5.337	14.518a	26.102a	18.321a	5.060	13.835a	24.773a	17.257a
S_3	5.688	14.149ab	24.941a	17.897a	5.414	13.508a	23.654a	16.875a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 9. Effect of boron on number of leaves at different days after sowing (DAS)

Boron	2012-2013				2013-2014			
	Number of leaves				Number of leaves			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
B_0	5.100	12.389b	18.827b	13.318b	4.829	11.992b	17.783b	12.540b
B_1	5.434	13.866a	24.271a	17.056a	5.162	13.248a	23.007a	16.058a
B_2	5.614	14.037a	24.689a	17.608a	5.348	13.394a	23.400a	16.585a
B_3	5.656	13.835a	24.203a	17.083a	5.387	13.235a	22.954a	16.103a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant — B_0= 0 kg B ha^{-1}
LS=level of significant — B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 10. Interaction effect of irrigation and sulpher on number of leaves at different days after sowing (DAS)

Interaction (I×S)	2012-2013				2013-2014			
	Number of leaves				Number of leaves			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0 S_0	5.267	10.742	15.361	9.596e	5.009	10.456	14.430	8.931e
I_0 S_1	5.452	12.980	21.090	15.786c	5.193	12.449	19.913	14.875c
I_0 S_2	5.298	13.533	22.685	16.779bc	5.022	12.976	21.483	15.843bc
I_0 S_3	5.861	13.433	22.578	17.047bc	5.590	12.908	21.407	16.141bc
I_1 S_0	5.267	12.811	18.962	13.131d	5.005	12.415	17.921	12.355d
I_1 S_1	5.452	13.987	24.862	17.792abc	5.182	13.317	23.547	16.742abc
I_1 S_2	5.298	15.173	28.968	20.001a	5.020	14.405	27.554	18.144a
I_1 S_3	5.828	14.557	26.686	18.474ab	5.554	13.843	25.326	16.979ab
I_2 S_0	5.200	12.066	18.530	12.695d	4.930	11.704	17.522	12.916d
I_2 S_1	5.698	13.795	24.038	17.544bc	5.430	13.236	22.824	16.499abc
I_2 S_2	5.416	14.849	26.653	18.182ab	5.139	14.122	25.281	16.673abc
I_2 S_3	5.374	14.457	25.558	18.169ab	5.098	13.773	24.228	16.650abc
LS	NS	NS	NS	0.05	NS	NS	NS	0.05

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NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 11. Interaction effect of irrigation and boron on number of leaves at different days after sowing (DAS)

Interaction (I×B)	2012-2013				2013-2014			
	Number of leaves				Number of leaves			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0 B_0	5.033	11.686	17.602c	12.126e	4.757	11.364	16.635c	11.424e
I_0 B_1	5.475	12.991	21.464b	15.636c	5.213	12.483	20.310b	14.748c
I_0 B_2	5.488	13.224	21.600b	15.872c	5.224	12.671	20.401b	14.939c
I_0 B_3	5.882	12.788	21.047b	15.574c	5.620	12.273	19.887b	14.679c
I_1 B_0	5.033	13.007	19.766bc	14.102d	4.769	12.566	18.679bc	13.281d
I_1 B_1	5.475	14.416	26.232a	18.002ab	5.197	13.721	24.892a	16.927ab
I_1 B_2	5.647	14.602	27.134a	19.233a	5.381	13.893	25.779a	18.144a
I_1 B_3	5.690	14.502	26.346a	18.061ab	5.414	13.801	24.998a	16.979ab
I_2 B_0	5.233	12.476	19.112bc	13.726d	4.959	12.046	18.036bc	12.916d
I_2 B_1	5.352	14.196	25.117a	17.531b	5.075	13.541	23.820a	16.499b
I_2 B_2	5.708	14.284	25.333a	17.719b	5.438	13.618	24.021a	16.673b
I_2 B_3	5.396	14.214	25.217a	17.614b	5.125	13.630	23.979a	16.650b
LS	NS	NS	0.01	0.05	NS	NS	0.01	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 12. Interaction effect of sulpher and boron on number of leaves at different days after sowing (DAS)

Interaction (S×B)	2012-2013				2013-2014			
	Number of leaves				Number of leaves			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
S_0 B_0	4.704	11.297	14.164g	7.132f	4.430	11.036	13.257g	6.491e
S_0 B_1	5.628	11.916	18.690f	13.147e	5.365	11.550	17.678f	12.401d
S_0 B_2	5.383	12.248	18.867f	13.651e	5.129	11.861	17.834ef	12.884d
S_0 B_3	5.261	12.032	18.750f	13.299e	5.001	11.656	17.727f	12.542d
S_1 B_0	5.311	12.517	19.822ef	14.749de	5.055	12.091	18.751ef	13.943cd
S_1 B_1	5.992	13.874	24.417cd	17.733bc	5.71	13.213	23.109cd	16.692b
S_1 B_2	5.483	14.010	24.594c	17.890bc	5.222	13.319	23.257cd	16.819b
S_1 B_3	5.350	13.948	24.487cd	17.790bc	5.084	13.380	23.262cd	16.842b
S_2 B_0	5.321	12.679	19.588ef	14.741de	5.047	12.221	18.484ef	13.903cd
S_2 B_1	4.956	15.060	27.769ab	18.967ab	4.673	14.314	26.377ab	17.841ab
S_2 B_2	5.346	15.222	29.040a	20.452a	5.072b	14.443	27.614a	19.293a
S_2 B_3	5.728	15.111	28.011ab	19.122ab	5.448	14.361	26.615ab	17.992ab
S_3 B_0	5.061	13.065	21.732de	16.649cd	4.782	12.620	20.641de	15.823bc
S_3 B_1	5.160	14.616	26.210abc	18.378abc	4.895	13.916	24.865abc	17.298ab
S_3 B_2	6.244	14.668	26.256abc	18.439abc	5.967	13.954	24.896abc	17.345ab
S_3 B_3	6.284	14.248	25.566bc	18.121bc	6.013	13.542	24.214bc	17.035b
LS	NS	NS	0.01	0.01	NS	NS	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

4.2. Growth characters

Study of growth characters i.e. total dry matter (TDM), crop growth rate (CGR), leaf area index (LAI) and net assimilation rate (NAR) in the growth period of mustard plant as affected by irrigation, sulpher and boron levels and their interaction.

4.2.1. Total dry matter (TDM)

Total dry matter (TDM) was significantly influenced by the irrigation levels at 40, 60 and 80 days after sowing (DAS) in both the years. At 40 DAS, the highest TDM was observed in two irrigations which were statistically similar to one irrigation in 2012-2013 and in 2013-2014, the highest TDM was observed in one irrigation. At 60 and 80 DAS in both the years, the highest value was obtained in one irrigation which was statistically identical with two irrigations. The lowest TDM was found in control in both the years (Table 13).

Different levels of sulpher had significant effect on total dry matter (TDM) at sampling dates 40, 60 and 80 DAS. At 40, 60 and 80 DAS in both the years, the highest TDM was found in S_2 treatment. This result was statistically similar to S_1 and S_3 treatments at 40 and 80 DAS in both trails and 60 DAS in 2013-2014. The lowest value was obtained in S_0 treatment (Table 14).

Boron levels had significant effect on total dry matter (TDM) at the all data collection period of growth cycle of mustard in both the years except 20 DAS. At 40, 60 and 80 DAS, the highest TDM was obtained from B_2 treatment which was statistically similar to B_1 and B_3 treatments and the lowest TDM was obtained from B_0 treatment in both the years (Table 15).

The interaction between irrigation and sulpher levels had significantly influenced on total dry matter (TDM) at 40, 60 and 80 DAS in both the years. At 40 DAS (2012-2013), the highest TDM was produced by the I_2S_2 treatment combination and in 2013-2014, the highest TDM was produced by the I_1S_2 treatment combination which was statistically similar to I_1S_3 and I_2S_2 treatment combinations. At 60 DAS in 2012-2013, the highest TDM was found in I_2S_2 treatment combination which was statistically similar to I_1S_2 and I_1S_3 treatment combinations and in 2013-2014, the highest TDM was found in I_1S_2 treatment combination. Finally at 80 DAS in both the years, the highest TDM was produced by the treatment combination of I_2S_2 which was statistically similar to I_2S_3, I_1S_2 and I_1S_3 treatment combinations. The minimum TDM was observed in the control treatment combination (Table 16).

The interaction between irrigation and boron levels had significantly influenced on TDM at 40 and 80 DAS in both trails and 60 DAS in 2012-2013. At 40 DAS in 2012-2013, the highest TDM was found in the I_1B_2 treatment combination which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combinations and in 2013-2014, the highest TDM was found in the I_1B_2 treatment combination which was statistically similar to I_1B_1 and I_1B_3 treatment combinations. At 60 DAS in 2012-2013, the highest TDM was observed in the I_1B_2 treatment combination which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combinations. At 80 DAS in both the years, I_1B_2 treatment combination gave the highest TDM which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combinations and B_0I_0 i.e. both of control treatment combination gave the lowest TDM (Table 17).

Interaction of sulpher and boron levels significantly influenced on TDM at data sampling dates of 40, 60 and 80 DAS in both the years. At 40 DAS 2012-2013, we showed that the highest TDM was found in the S_2B_2 treatment combination which was statistically similar to S_1B_1, S_1B_2, S_1B_3, S_2B_1, S_2B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations and in 2013-2014, the highest TDM was found in the S_2B_2 treatment combination which was statistically similar to S_2B_1, S_2B_3 and S_3B_2 treatment combinations. At 60 DAS in 2012-2013, the highest TDM was observed in the S_2B_2 treatment combination which was statistically similar to S_2B_3 and in 2013-2014, S_2B_2 treatment combination gave the highest TDM which was statistically similar to S_1B_1, S_1B_2, S_1B_3, S_2B_1, S_2B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations. At 80 DAS in both the years, S_2B_2 treatment combination gave the highest TDM and control treatment combination produced the lowest TDM (Table 18).

Table 13. Effect of irrigation on total dry matter plant^{-1}(g) at different days after sowing (DAS)

Irrigation	2012-2013				2013-2014			
	Total dry matter				Total dry matter			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0	0.241	0.722b	4.540b	7.134b	0.2666	0.610b	5.166b	7.824b
I_1	0.244	0.834a	5.585a	8.317a	0.271	0.773a	6.072a	9.667a
I_2	0.245	0.837a	5.482a	8.241a	0.273	0.721ab	5.934a	9.415a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

Table 14. Effect of sulpher on total dry matter plant^{-1} (g) at different days after sowing (DAS)

Sulpher	2012-2013				2013-2014			
	Total dry matter				Total dry matter			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
S_0	0.241	0.543b	3.757c	5.375b	0.263	0.483b	3.899b	6.400b
S_1	0.244	0.857a	5.374b	8.437a	0.266	0.725a	6.075a	9.283a
S_2	0.241	0.897a	5.942a	8.965a	0.277	0.819a	6.577a	10.305a
S_3	0.246	0.894a	5.737ab	8.812a	0.273	0.777a	6.344a	9.887a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 15. Effect of boron on total dry matter plant^{-1} (g) at different days after sowing (DAS)

Boron	2012-2013				2013-2014			
	Total dry matter				Total dry matter			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
B_0	0.239	0.589b	4.034b	5.833b	0.271	0.534b	4.146b	6.761b
B_1	0.245	0.859a	5.515a	8.521a	0.272	0.754a	6.182a	9.538a
B_2	0.245	0.881a	5.646a	8.681a	0.266	0.779a	6.361a	9.862a
B_3	0.244	0.862a	5.613a	8.554a	0.269	0.739a	6.206a	9.713a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability

NS= not significant
LS=level of significant

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

.

Table 16. Interaction effect of irrigation and sulpher on total dry matter plant^{-1} (g) at different days after sowing (DAS)

Interaction (I×S)	2012-2013				2013-2014			
	Total dry matter				Total dry matter			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
$I_0 S_0$	0.232	0.490h	3.347f	4.954e	0.257	0.421e	3.685f	5.802e
$I_0 S_1$	0.245	0.781f	4.728d	7.681d	0.259	0.667d	5.530e	8.120d
$I_0 S_2$	0.238	0.817e	5.145cd	8.039bcd	0.276	0.692cd	5.788cde	8.870bcd
$I_0 S_3$	0.247	0.799ef	4.940d	7.861cd	0.270	0.661d	5.660de	8.502cd
$I_1 S_0$	0.244	0.578g	4.012e	5.689e	0.262	0.532e	4.066f	6.749e
$I_1 S_1$	0.242	0.902cd	5.794ab	8.894ab	0.270	0.806abc	6.404abc	10.039ab
$I_1 S_2$	0.243	0.903cd	6.327a	9.278a	0.279	0.903a	7.045a	10.999a
$I_1 S_3$	0.246	0.954ab	6.207a	9.407a	0.273	0.850a	6.773ab	10.883a
$I_2 S_0$	0.248	0.561g	3.911e	5.482e	0.270	0.498e	3.947f	6.649e
$I_2 S_1$	0.243	0.887d	5.600bc	8.738abc	0.267	0.703bcd	6.291bcd	9.690abc
$I_2 S_2$	0.242	0.971a	6.353a	9.579a	0.277	0.863a	6.897ab	11.045a
$I_2 S_3$	0.245	0.930bc	6.064ab	9.167a	0.276	0.820ab	6.600ab	10.275a
LS	NS	0.05	0.01	0.01	NS	0.01	0.05	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 17. Interaction effect of irrigation and boron on total dry matter plant^{-1} (g) at different days

Interaction (I×B)	2012-2013				2013-2014			
	Total dry matter				Total dry matter			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
$I_0 B_0$	0.235	0.525d	3.547d	5.297d	0.276	0.458e	3.682	5.995d
$I_0 B_1$	0.243	0.784b	4.840b	7.713b	0.262	0.644cd	5.553	8.323b
$I_0 B_2$	0.245	0.791b	4.899b	7.778b	0.264	0.689bcd	5.850	8.594b
$I_0 B_3$	0.240	0.788b	4.874b	7.747b	0.261	0.651cd	5.578	8.383b
$I_1 B_0$	0.242	0.631c	4.312c	6.220c	0.264	0.577de	4.449	7.288c
$I_1 B_1$	0.243	0.883a	5.844a	8.892a	0.278	0.831a	6.542	10.129a
$I_1 B_2$	0.244	0.936a	6.112a	9.235a	0.266	0.845a	6.732	10.711a
$I_1 B_3$	0.246	0.886a	6.073a	8.921a	0.276	0.838a	6.565	10.542a
$I_2 B_0$	0.240	0.611c	4.245c	5.982c	0.273	0.566d	4.307	7.000c
$I_2 B_1$	0.248	0.909a	5.862a	8.958a	0.277	0.788ab	6.450	10.161a
$I_2 B_2$	0.245	0.916a	5.929a	9.031a	0.270	0.802ab	6.502	10.281a
$I_2 B_3$	0.245	0.912a	5.892a	8.995a	0.271	0.728abc	6.476	10.216a
LS	NS	0.05	0.01	0.01	NS	0.01	NS	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 18. Interaction effect of sulpher and boron on total dry matter plant^{-1} (g) at different days after sowing (DAS)

Interaction (S×B)	2012-2013				2013-2014			
	Total dry matter				Total dry matter			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
S_0 B_0	0.235	0.383c	3.161d	4.004e	0.276	0.397e	2.667c	5.189e
S_0 B_1	0.240	0.595b	3.932c	5.815d	0.263	0.502cd	4.187b	6.688d
S_0 B_2	0.246	0.598b	3.973c	5.855d	0.254	0.523cd	4.549b	6.984d
S_0 B_3	0.244	0.596b	3.960c	5.826d	0.260	0.513cd	4.195b	6.738d
S_1 B_0	0.238	0.635b	4.226c	6.215cd	0.256	0.562c	4.475b	7.216d
S_1 B_1	0.245	0.927a	5.716b	9.139b	0.279	0.798ab	6.580a	9.899c
S_1 B_2	0.245	0.935a	5.801b	9.218b	0.261	0.827ab	6.637a	10.051abc
S_1 B_3	0.246	0.931a	5.753b	9.178b	0.266	0.715b	6.608a	9.966bc
S_2 B_0	0.239	0.684b	4.443c	6.712c	0.274	0.594c	4.833b	7.607d
S_2 B_1	0.242	0.943a	6.234ab	9.547ab	0.282	0.882a	7.060a	10.831abc
S_2 B_2	0.246	1.013a	6.562a	10.004a	0.273	0.916a	7.314a	11.422a
S_2 B_3	0.238	0.948a	6.527a	9.598ab	0.279	0.886a	7.100a	11.359abc
S_3 B_0	0.242	0.653b	4.309c	6.402cd	0.279	0.582c	4.609b	7.032d
S_3 B_1	0.252	0.971a	6.178ab	9.583ab	0.265	0.835ab	6.900a	10.731ab
S_3 B_2	0.242	0.978a	6.249ab	9.646ab	0.278	0.850a	6.945a	10.991abc
S_3 B_3	0.247	0.974a	6.212ab	9.615ab	0.272	0.842ab	6.923a	10.791abc
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

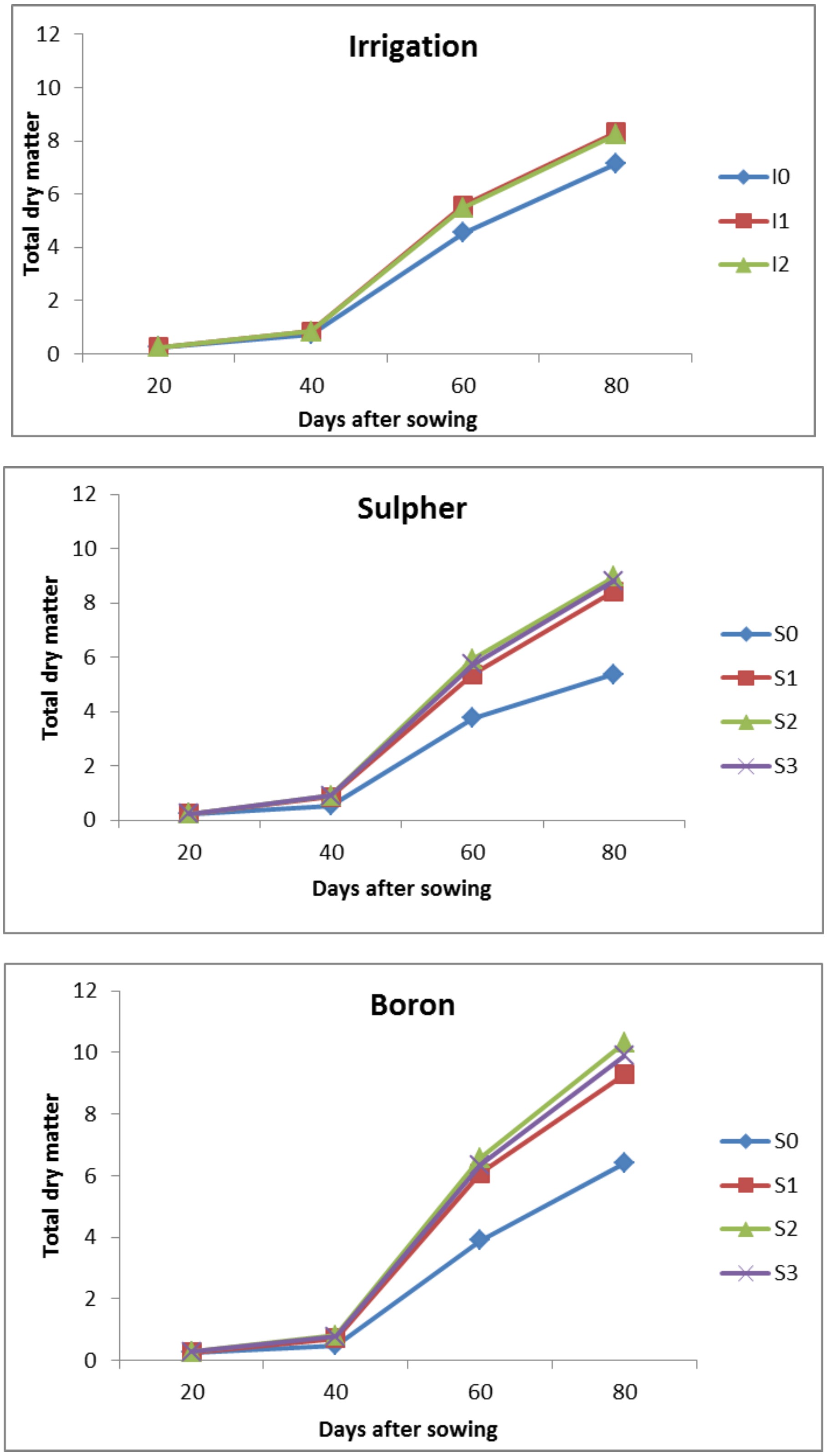


Figure 1. Effect of irrigation, sulpher and boron of total dry matter at different days after sowing (DAS) in 2012-2013

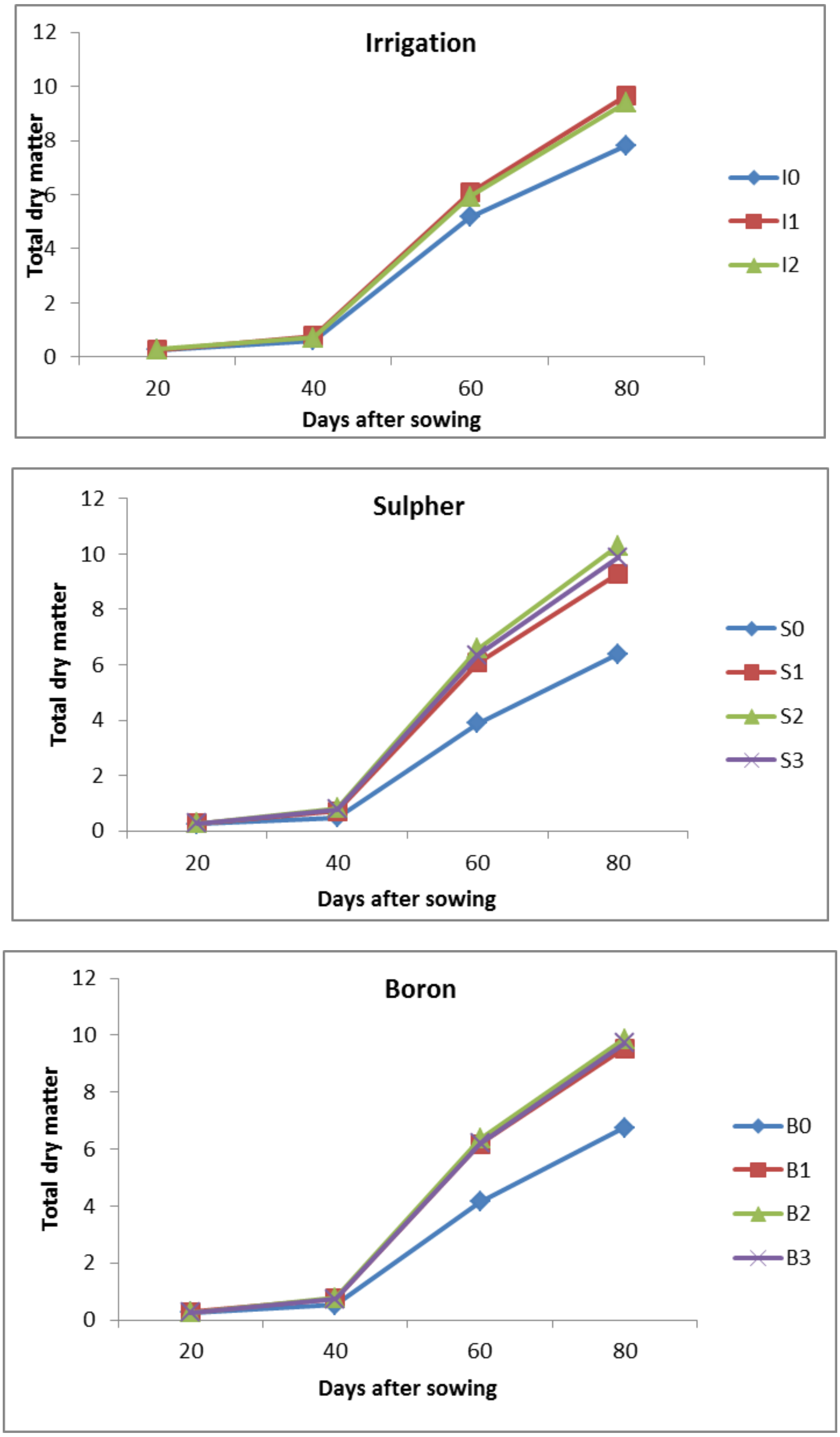


Figure 2. Effect of irrigation, sulpher and boron of total dry matter at different days after sowing (DAS) in 2013-2014

4.2.3. Crop growth rate (CGR)

Irrigation levels had significant effect on crop growth rate (CGR) at 20-40 and 40-60 in both the years and 60-80 DAS in 2013-2014. During the period of 20-40 DAS in 2012-2013, the highest CGR was observed in I_2 treatment which was similar to I_1 treatment and in 2013-2014, the highest CGR was observed in I_1 treatment. At 40-60 DAS in both trails, the highest CGR was obtained in I_1 treatment which was similar to I_2 treatment. Finally 60-80 DAS in 2013-2014, the maximum CGR was produced by I_1 treatment which was statistically similar to I_2 treatment and the lowest CGR was produced by I_0 (no irrigation) treatment (Table 19).

Result showed that crop growth rate (CGR) had significant effect on the sulpher levels at all sampling dates such as 20-40 DAS, 40-60 DAS and 60-80 DAS. Within the period of 20-40 (2012-2013), the highest CGR was found in S_2 treatment which was statistically similar to S_1 and S_3 treatments and in 2013-2014, the highest value was obtained in S_1 treatment which was statistically similar to S_2 and S_3 treatments. At time interval of 40-60 DAS in 2012-2013, the highest CGR was produced by S_2 treatment which was similar to S_3 treatment and in 2013-2014, the highest value was found in S_2 treatment which was similar to S_1 and S_3 treatments. Finally 60-80 DAS, the S_3 treatment was produced the highest CGR which was statistically similar to S_1 and S_2 treatments in 2012-2013 and in 2013-2014, the highest CGR was found in S_2 treatment which was similar to S_3 treatment. The lowest CGR was produced by S_0 treatment (Table 20).

Boron levels had significant effect on crop growth rate (CGR) at all data collection period of growth cycle in both the years. During the period of

20-40 and 40-60 DAS in both trails, the maximum CGR was produced by B_2 treatment which was statistically similar to B_1 and B_3 treatments. Within interval of 60-80 DAS (2012-2013), the highest CGR was found in the B_2 treatment which was statistically identical with B_1 and B_3 treatments and in 2013-2014, the highest value was obtained in B_3 treatment which was statistically similar with B_1 and B_2 treatment. The lowest CGR was obtained in B_0 treatment (Table 21).

Interaction effect of irrigation and sulpher levels had significant effect on crop growth rate (CGR) at 20-40 and 60-80 DAS in both trails and 40-60 DAS in 2012-2013. The time interval of 20-40 DAS (2012-2013), the highest CGR was found in I_2S_2 treatment combination which was statistically similar to I_1S_3 and I_2S_3 treatment combinations and in 2013-2014, the highest CGR was obtained in the treatment combination of I_1S_2 which was statistically similar to I_1S_1, I_1S_3, I_2S_2 and I_2S_3 treatment combinations. At 40-60 DAS in 2012-2013, the treatment combination of I_1S_2 and I_2S_2 showed statistically identical CGR. Finally 60-80 DAS 2012-2013, the highest CGR was observed in I_2S_2 treatment combination which was statistically identical with I_2S_1, I_2S_3, I_1S_1, I_1S_2 and I_1S_3 treatment combinations in 2012-2013 and in 2013-2014, the highest CGR was observed in I_2S_2 treatment combination which was statistically identical with I_1S_3 treatment combinations. The lowest CGR was obtained in the I_0S_0 treatment combination (Table 22).

The Interaction between irrigation and boron levels had shown statistically significant effect on crop growth rate (CGR) at 20-40 DAS in both the years and 40-60 DAS (2012-2013). During the period of 20-40 DAS (2012-2013), the highest CGR was observed from I_1B_2 treatment combination which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and

I_2B_3 treatment combinations and in 2013-2014, the highest CGR was found in I_1B_2 treatment combination which was statistically similar to I_1B_1 and I_1B_3 treatment combinations. Within the period of 40-60 DAS in 2012-2013, the treatment combination of I_1B_3 gave the highest CGR which was statistically identical with I_1B_1, I_1B_2, I_2B_1, I_2B_2 and I_2B_3 treatment combinations. The lowest CGR was obtained in the I_0B_0 treatment combination (Table 23).

The interaction between sulpher and boron levels had significantly influenced on CGR at 20-40, 40-60 and 60-80 DAS in both the years. Within the period of 20-40 DAS, the highest CGR was found in S_2B_2 treatment combination which was statistically identical with S_2B_1, S_2B_3, S_1B_1, S_1B_2, S_1B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in 2012-2013 and in 2013-2014, the highest CGR was found in S_2B_2 treatment combination which was statistically identical with S_2B_1 and S_2B_3, treatment combinations. At 40-60 DAS (2012-2013), the highest CGR was obtained from S_2B_3 treatment combination which was statistically identical with S_2B_2 treatment combination and in 2013-2014, the highest value was obtained from S_2B_2 treatment combination. During the period of 60-80 DAS, the highest CGR was produced by the interaction of S_2B_2, S_2 (40kg S ha^{-1}) with B_2 (1.5 kg B ha^{-1}) combination which was statistically identical with S_1B_1, S_1B_2, S_1B_3, S_2B_1, S_2B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in 2012-2013 and in 2013-2014, the highest value was found in S_2B_3 treatment combination. The lowest CGR was produced by the interaction of S_0B_0 i.e. both of control treatment combination (Table 24).

Table 19. Effect of irrigation on crop growth rate ($gm^{-2}day^{-1}$) at different days after sowing (DAS)

Irrigation	2012-2013			2013-2014		
	Crop growth rate			Crop growth rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
I_0	2.406b	19.354b	12.969	1.723c	22.777b	13.289b
I_1	2.953a	23.754a	13.660	2.508a	26.497a	17.977a
I_2	2.963a	23.119a	13.902	2.242b	26.064a	17.405a
LS	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

Table 20. Effect of sulpher on crop growth rate ($gm^{-2}day^{-1}$) at different days after sowing (DAS)

Sulpher	2012-2013			2013-2014		
	Crop growth rate			Crop growth rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
S_0	1.508b	15.930c	8.230b	1.101b	17.079b	12.503b
S_1	3.066a	22.586b	15.318a	2.999a	26.748a	16.040ab
S_2	3.279a	25.223a	15.119a	2.711a	28.787a	18.641a
S_3	3.242a	24.214a	15.373a	2.520a	27.836a	17.711a
LS	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 21. Effect of boron on crop growth rate ($gm^{-2}day^{-1}$) at different days after sowing (DAS)

Boron	2012-2013			2013-2014		
	Crop growth rate			Crop growth rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
B_0	1.750b	17.089b	9.132b	1.312b	18.062b	13.075b
B_1	3.071a	23.282a	15.029a	2.409a	27.138a	16.779a
B_2	3.183a	23.826a	15.173a	2.562a	27.913a	17.504a
B_3	3.092a	23.755a	14.706a	2.348a	27.337a	17.536a
LS	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant B_0= 0 kg B ha^{-1}
LS=level of significant B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 22. Interaction effect of irrigation and sulpher on crop growth rate (gm^{-2} day^{-1}) at different days after sowing (DAS)

Interaction (I×S)	2012-2013 Crop growth rate			2013-2014 Crop growth rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
I_0 S_0	1.228e	14.286g	8.035b	0.818d	16.320	10.583f
I_0 S_1	2.680d	19.734ef	14.764ab	2.038b	24.315	12.950ef
I_0 S_2	2.895bcd	21.638cde	14.472ab	2.080b	25.480	15.410cde
I_0 S_3	2.762cd	20.706de	14.604ab	1.954b	24.993	14.212de
I_1 S_0	1.671e	17.172fg	8.383b	1.349c	17.671	13.413ef
I_1 S_1	3.303ab	24.456abc	15.503a	2.678a	27.992	18.174abc
I_1 S_2	3.298ab	27.122a	14.752a	3.123a	30.710	19.770ab
I_1 S_3	3.540a	26.267ab	15.999a	2.884a	29.614	20.549a
I_2 S_0	1.566e	16.331fg	8.273b	1.137cd	17.247	13.511ef
I_2 S_1	3.217abc	23.567bcd	15.687a	2.181b	27.938	16.996bcd
I_2 S_2	3.644a	26.910a	16.131a	2.929a	30.171	20.741a
I_2 S_3	3.425a	25.670ab	15.515a	2.721a	28.899	18.372abc
LS	0.05	0.01	0.05	0.01	NS	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 23. Interaction effect of irrigation and boron on crop growth rate ($gm^{-2}day^{-1}$) at different days after sowing (DAS)

Interaction (I×B)	2012-2013			2013-2014		
	Crop growth rate			Crop growth rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
I_0 B_0	1.448d	15.114c	8.750	0.908f	16.122	11.565
I_0 B_1	2.708b	20.280b	14.361	1.909cd	24.546	13.847
I_0 B_2	2.732b	20.539b	14.396	2.125c	25.805	13.721
I_0 B_3	2.738b	20.429b	14.368	1.948c	24.636	14.023
I_1 B_0	1.944c	18.404b	9.544	1.562de	19.359	14.195
I_1 B_1	3.203a	24.802a	15.242	2.763a	28.557	17.933
I_1 B_2	3.461a	25.877a	15.615	2.898a	29.435	19.895
I_1 B_3	3.202a	25.935a	14.238	2.811a	28.636	19.884
I_2 B_0	1.858c	17.750b	9.103	1.465e	18.705	13.466
I_2 B_1	3.302a	24.765a	15.483	2.554ab	28.312	18.556
I_2 B_2	3.356a	25.063a	15.510	2.663ab	28.498	18.897
I_2 B_3	3.337a	24.900a	15.510	2.285bc	28.739	18.701
LS	0.05	0.01	NS	0.05	NS	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 24. Interaction effect of sulpher and boron on crop growth rate (gm^{-2} day^{-1}) at different days after sowing (DAS)

Interaction (S×B)	2012-2013			2013-2014		
	Crop growth rate			Crop growth rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
S_0 B_0	0.740c	13.333d	4.769c	0.606d	11.348d	12.611e
S_0 B_1	1.773b	16.690c	9.412b	1.193c	18.426c	12.508e
S_0 B_2	1.764b	16.874c	9.411b	1.343c	20.133c	12.174e
S_0 B_3	1.756b	16.822c	9.330b	1.262c	18.410c	12.717e
S_1 B_0	1.982b	17.956c	9.946b	1.528c	19.566c	13.707e
S_1 B_1	3.409a	23.946b	17.114a	2.593ab	28.912b	16.595d
S_1 B_2	3.451a	24.329b	17.089a	2.831ab	29.050ab	17.070cd
S_1 B_3	3.424a	24.112b	17.123a	2.243b	29.466ab	16.788d
S_2 B_0	2.224b	18.792c	11.349b	1.598c	21.196c	13.869e
S_2 B_1	3.503a	26.458ab	16.564a	2.997a	30.893ab	18.856bc
S_2 B_2	3.839a	27.745a	17.207a	3.213a	31.991a	20.543ab
S_2 B_3	3.549a	27.898a	15.355a	3.034a	31.068ab	21.295a
S_3 B_0	2.054b	18.278c	10.466b	1.514c	20.139c	12.157e
S_3 B_1	3.598a	26.036ab	17.024a	2.852ab	30.323ab	19.157b
S_3 B_2	3.678a	26.356ab	16.987a	2.861ab	30.477ab	20.230ab
S_3 B_3	3.639a	26.187ab	17.015a	2.852ab	30.403ab	19.343ab
LS	0.01	0.01	0.01	0.01	0.05	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

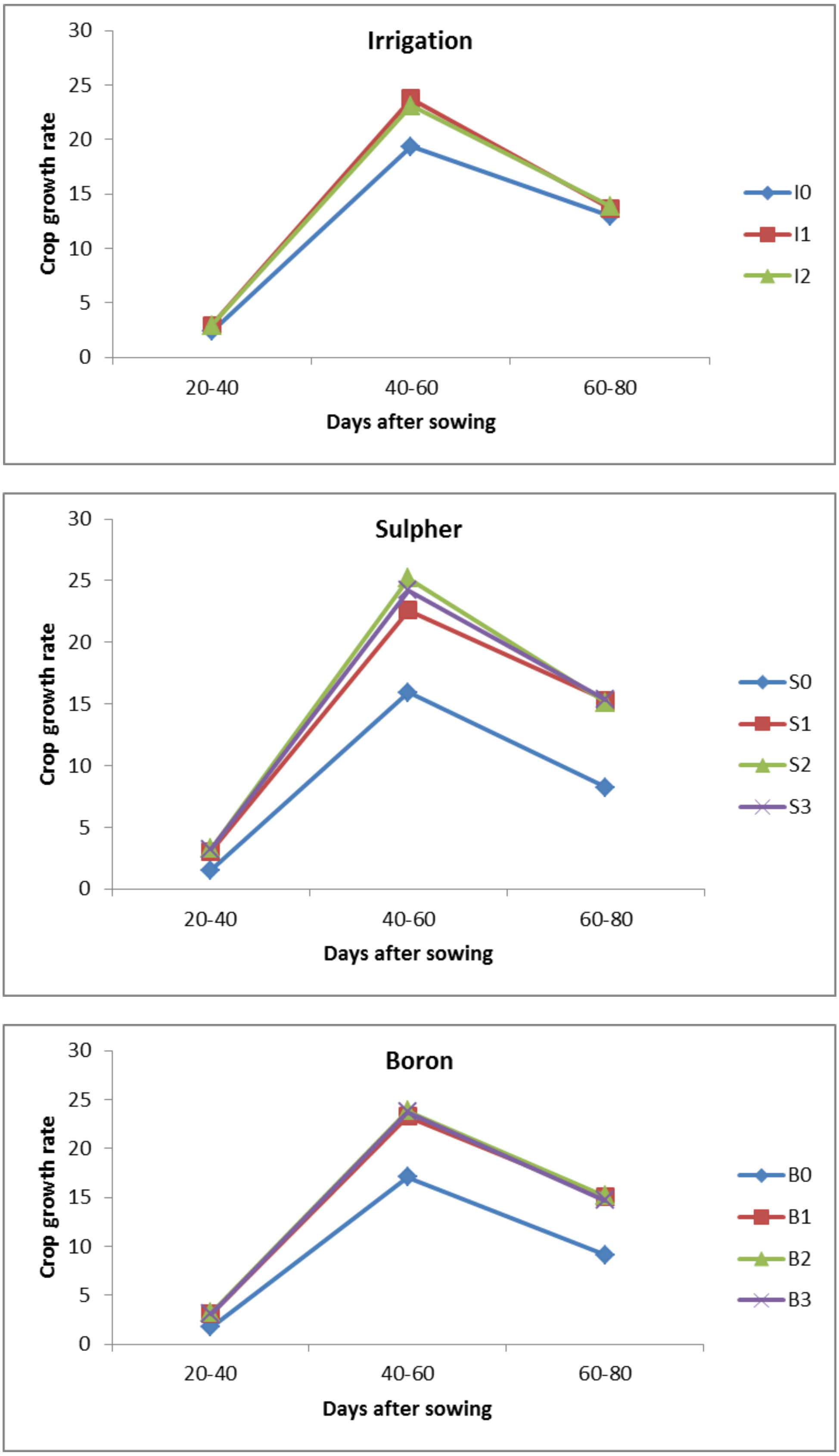


Figure 3. Effect of irrigation, sulpher and boron of crop growth rate at different days after sowing (DAS) in 2012-2013

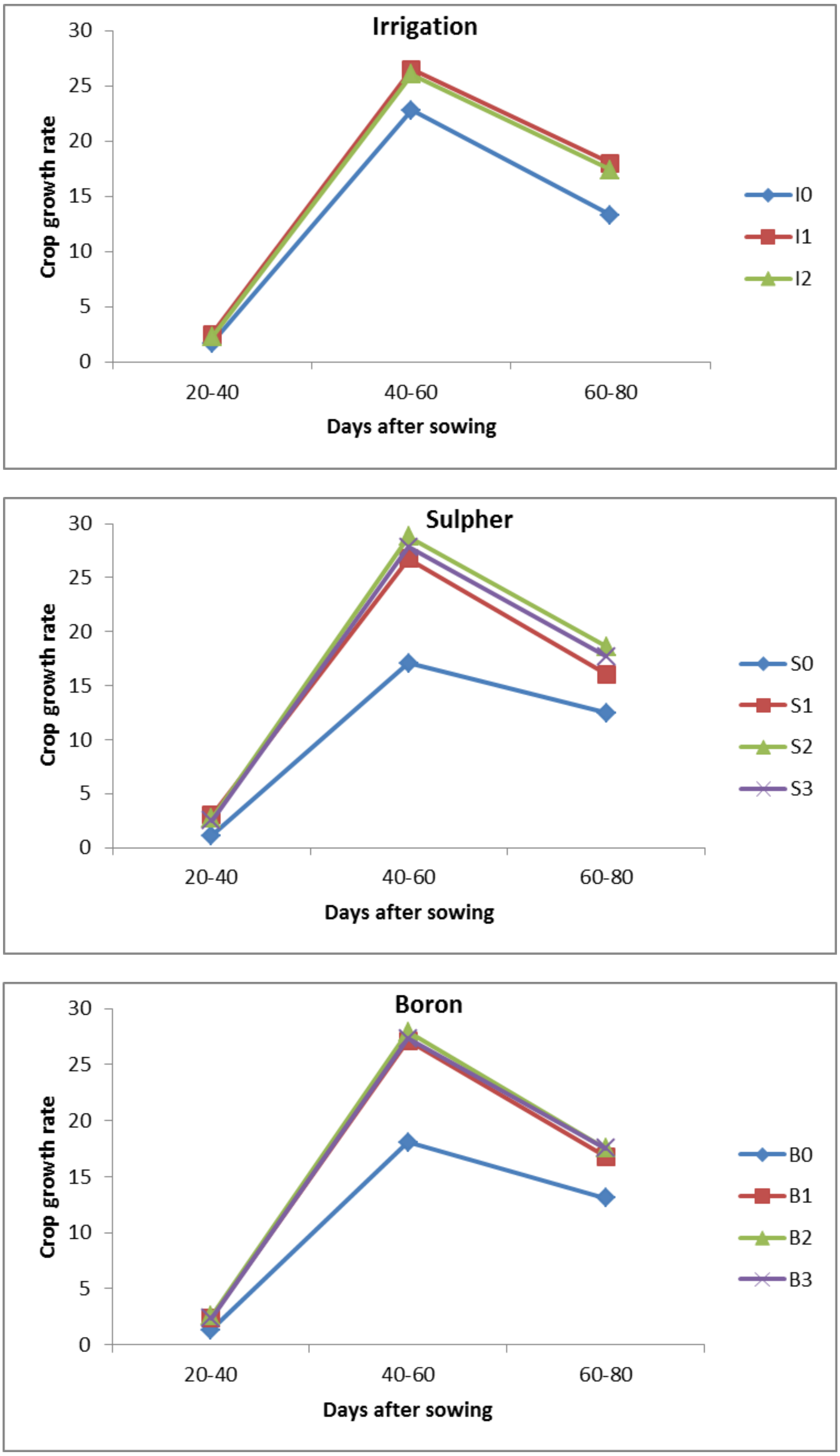


Figure 4. Effect of irrigation, sulpher and boron of crop growth rate at different days after sowing (DAS) in 2013-2014

4.2.3. Leaf area index (LAI)

Irrigation levels had significant effect on LAI at 40, 60 and 80 DAS in both the years. At 40 DAS (2012-2013 and 2013-2014), one irrigation gave the higher LAI. The highest LAI was observed when field was received one irrigation at 60 and 80 DAS in both the years which was statistically identical with two irrigations. The lowest LAI was obtained in control in both years (Table 25).

Sulpher levels had significant effect on LAI at all sampling dates except 20 DAS. At 40, 60 and 80 DAS in both the years, the highest LAI was found in S_2 treatment which was statistically similar to S_1 and S_3 treatments. The lowest LAI was obtained in control in both the years (Table 26).

LAI was significantly influenced due to in boron levels at 40, 60 and 80 DAS in both the years. At 40 DAS, the highest LAI was observed B_2 treatment. At 60 and 80 DAS, B_2 treatment gave the higher LAI which was statistically similar to B_1 and B_3 treatments. The lowest result was obtained in control in both the years (Table 27).

The interaction between irrigation and sulpher levels had significant effect on LAI at 40 and 80 DAS in both trails and 60 DAS in 2012-2013. At 40 DAS, the highest LAI was observed in the treatment combination of I_1S_2 in both the years. At 60 DAS in 2012-2013, the highest value was found in the treatment combination of I_1S_2 which was statistically identical with I_1S_3 treatment combination. At 80 DAS in both the years, the treatment combination of I_1S_2 produced the highest LAI. The lowest result was obtained in control in both the years (Table 28).

LAI showed significant variation due to interaction of irrigation and boron levels at 40 DAS in both the years and 60 and 80 DAS in 2012-2013. At 40, 60 and 80 DAS in 2012-2013, the highest LAI was observed in I_1B_2 treatment combination. At 40 DAS in 2013-2014, the highest LAI was found in I_1B_2 treatment combination which was statistically identical with I_1B_1 and I_1B_3 treatment combinations. The lowest result was obtained in control in both the years (Table 29).

Sulpher and boron treatment combination had significant effect on LAI at 40, 60 and 80 DAS in both the years. The highest LAI was obtained from S_2B_2 treatment combination at 40 DAS in both the years. At 60 DAS in both trails, S_2B_2 treatment combination produced the highest LAI. This result was identical with S_2B_{1}-, S_2B_3, S_1B_1, S_1B_2, S_1B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in 2013-2014. At 80 DAS in both the years, treatment combination of S_2B_2 gave the highest LAI which was statistically identical with of S_1B_1, S_1B_2, S_1B_3, S_2B_1, S_2B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations. The lowest result was obtained in control in both years (Table 30).

Table 25. Effect of irrigation on leaf area index at different days after sowing (DAS)

Irrigation	2012-2013				2013-2014			
	Leaf area index				Leaf area index			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0	0.053	0.500c	1.353b	2.278b	0.053	0.474b	1.521b	2.313b
I_1	0.054	0.668a	1.733a	2.640a	0.054	0.641a	1.697a	2.634a
I_2	0.055	0.620b	1.625a	2.508a	0.055	0.595ab	1.658a	2.549a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant I_0 = Control
LS=level of significant I_1 = One irrigation
I_2 = Two irrigations

Table 26. Effect of sulpher on leaf area index at different days after sowing (DAS)

Sulpher	2012-2013				2013-2014			
	Leaf area index				Leaf area index			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
S_0	0.053	0.373c	1.011b	1.801b	0.053	0.353c	1.171b	1.848b
S_1	0.054	0.628b	1.643a	2.601a	0.054	0.603a	1.709a	2.634a
S_2	0.055	0.713a	1.864a	2.802a	0.055	0.683a	1.849a	2.807a
S_3	0.055	0.669ab	1.763a	2.696a	0.055	0.641a	1.744a	2.705a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 27. Effect of boron on leaf area index at different days after sowing (DAS)

Boron	2012-2013				2013-2014			
	Leaf area index				Leaf area index			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
B_0	0.054	0.421c	1.168b	1.765b	0.054	0.397c	1.229b	1.801b
B_1	0.054	0.643b	1.669a	2.668a	0.054	0.618b	1.728a	2.707a
B_2	0.053	0.679a	1.767a	2.785a	0.053	0.648a	1.799a	2.767a
B_3	0.054	0.642b	1.678a	2.682a	0.054	0.617b	1.745a	2.720a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

B_0= 0 kg S ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 28. Interaction effect of irrigation and sulpher on leaf area index at different days after sowing (DAS)

Interaction (I×S)	2012-2013				2013-2014			
	Leaf area index				Leaf area index			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0 S_0	0.052	0.306f	0.785h	1.532f	0.052	0.285e	1.115	1.596e
I_0 S_1	0.052	0.558d	1.488f	2.492d	0.052	0.531c	1.633	2.517abc
I_0 S_2	0.055	0.585d	1.590def	2.540cd	0.055	0.556c	1.678	2.575abc
I_0 S_3	0.054	0.549d	1.550ef	2.547cd	0.054	0.525c	1.656	2.563abc
I_1 S_0	0.052	0.428e	1.146g	1.999e	0.052	0.412d	1.297	2.038f
I_1 S_1	0.054	0.693bc	1.755bcd	2.694bcd	0.054	0.670b	1.754	2.731ab
I_1 S_2	0.056	0.801a	2.098a	3.008a	0.056	0.767a	1.939	2.955a
I_1 S_3	0.055	0.749ab	1.934a	2.859abc	0.055	0.714ab	1.796	2.812ab
I_2 S_0	0.054	0.385ef	1.102bc	1.871e	0.054	0.362de	1.184	1.910c
I_2 S_1	0.055	0.633cd	1.686g	2.617bcd	0.055	0.609c	1.739	2.656abc
I_2 S_2	0.055	0.754ab	1.904cde	2.829ab	0.055	0.727ab	1.931	2.892ab
I_2 S_3	0.055	0.709bc	1.806b	2.683bcd	0.055	0.684ab	1.780	2.739ab
LS	NS	0.01	0.05	0.05	NS	0.01	NS	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 29. Interaction effect of irrigation and boron on leaf area index at different days after sowing (DAS)

Interaction (I×B)	2012-2013				2013-2014			
	Leaf area index				Leaf area index			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
I_0 B_0	0.094	0.343h	0.952d	1.630c	0.055	0.322e	1.150	1.666
I_0 B_1	0.054	0.531f	1.477bc	2.479b	0.052	0.508cd	1.638	2.515
I_0 B_2	0.054	0.586e	1.498bc	2.511b	0.053	0.553c	1.652	2.544
I_0 B_3	0.054	0.538f	1.486bc	2.490b	0.052	0.515cd	1.643	2.526
I_1 B_0	0.052	0.464g	1.289c	1.857c	0.053	0.414d	1.273	1.893
I_1 B_1	0.056	0.720b	1.796ab	2.803ab	0.056	0.695a	1.796	2.838
I_1 B_2	0.052	0.759a	2.040a	3.083a	0.053	0.726a	1.910	2.952
I_1 B_3	0.055	0.727ab	1.807ab	2.817ab	0.055	0.702a	1.806	2.853
I_2 B_0	0.055	0.454g	1.262cd	1.809c	0.055	0.430d	1.264	1.844
I_2 B_1	0.055	0.677cd	1.733ab	2.723ab	0.055	0.651ab	1.751	2.768
I_2 B_2	0.053	0.691c	1.763ab	2.761ab	0.054	0.666ab	1.834	2.804
I_2 B_3	0.054	0.659d	1.741ab	2.738ab	0.056	0.633bc	1.785	2.781
LS	NS	0.01	0.01	0.01	NS	0.01	NS	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0 = 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 30. Interaction effect of sulpher and boron on leaf area index at different days after sowing (DAS)

Interaction (S×B)	2012-2013				2013-2014			
	Leaf area index				Leaf area index			
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
$S_0 B_0$	0.056	0.283j	0.732d	1.333c	0.055	0.261f	0.973c	1.338c
$S_0 B_1$	0.053	0.388i	1.094c	1.905b	0.053	0.366e	1.230b	1.967b
$S_0 B_2$	0.051	0.420h	1.114c	2.044b	0.051	0.409de	1.356b	2.106b
$S_0 B_3$	0.052	0.399hi	1.103c	1.920b	0.052	0.377de	1.237b	1.982b
$S_1 B_0$	0.051	0.448g	1.255c	1.835b	0.051	0.426de	1.293b	1.892b
$S_1 B_1$	0.056	0.686d	1.763b	2.840a	0.056	0.662b	1.837a	2.867a
$S_1 B_2$	0.052	0.720c	1.784b	2.875a	0.052	0.692ab	1.851a	2.899a
$S_1 B_3$	0.053	0.659e	1.769b	2.854a	0.055	0.634c	1.853a	2.880a
$S_2 B_0$	0.055	0.481f	1.354c	1.986b	0.055	0.458d	1.333b	2.024b
$S_2 B_1$	0.057	0.772b	1.959ab	3.020a	0.056	0.746ab	1.969a	3.052a
$S_2 B_2$	0.054	0.824a	2.174a	3.171a	0.055	0.780a	2.092a	3.090a
$S_2 B_3$	0.057	0.777b	1.970ab	3.032a	0.056	0.750ab	2.003a	3.063a
$S_3 B_0$	0.106	0.470fg	1.330c	1.907b	0.056	0.446de	1.317b	1.949b
$S_3 B_1$	0.054	0.724c	1.859ab	2.908a	0.053	0.699ab	1.877a	2.943a
$S_3 B_2$	0.055	0.750c	1.996ab	3.051a	0.056	0.714ab	1.895a	2.972a
$S_3 B_3$	0.055	0.731c	1.869ab	2.921a	0.054	0.706ab	1.886a	2.955a
LS	NS	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

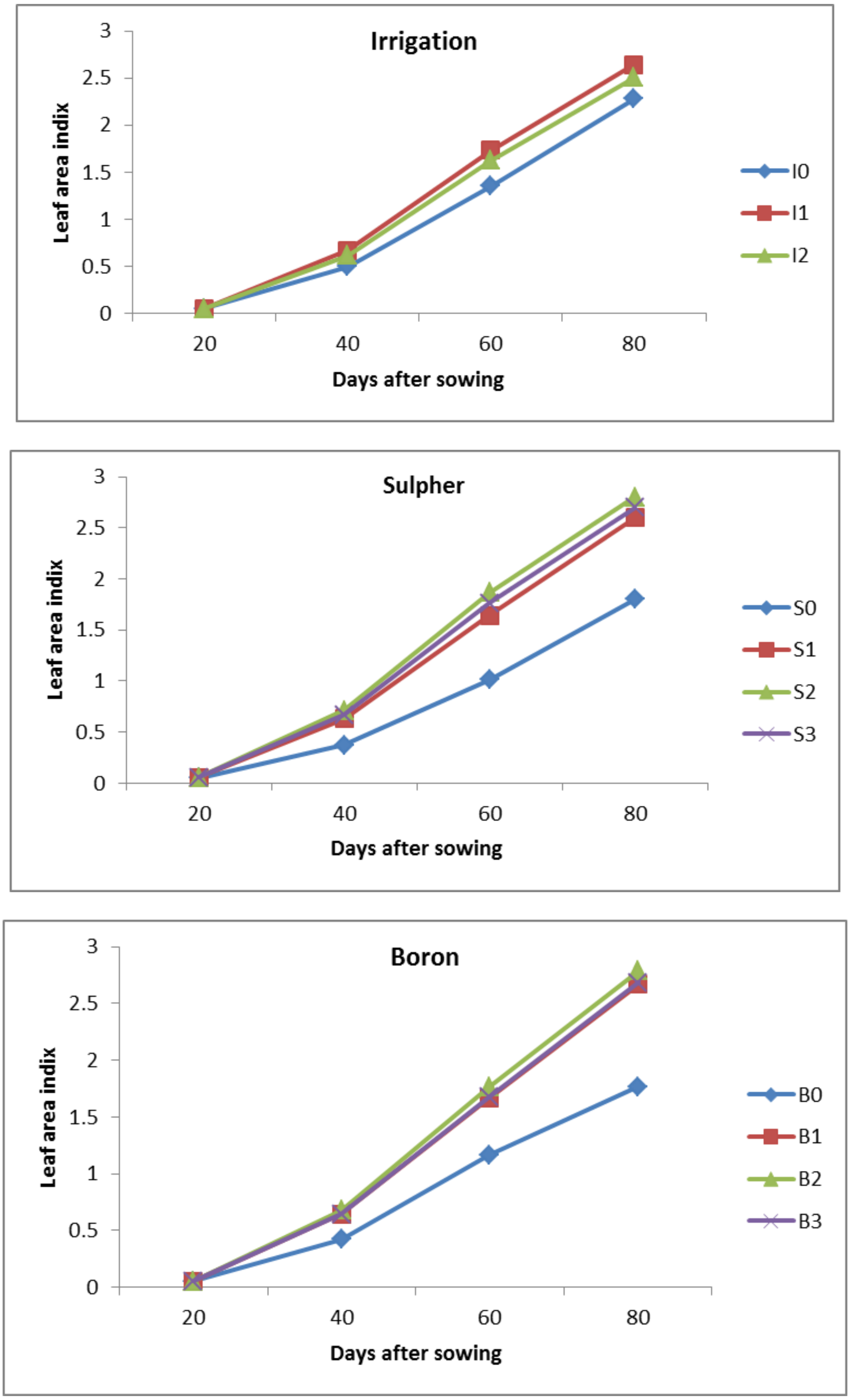
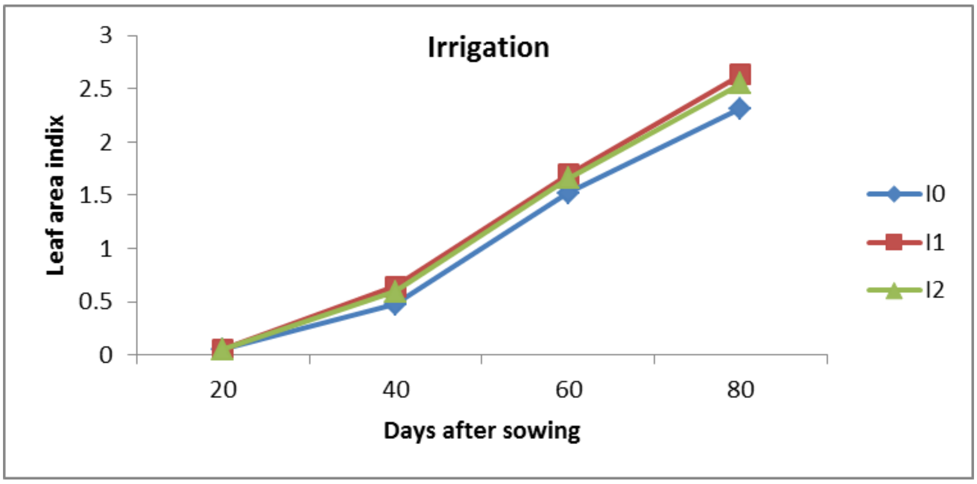
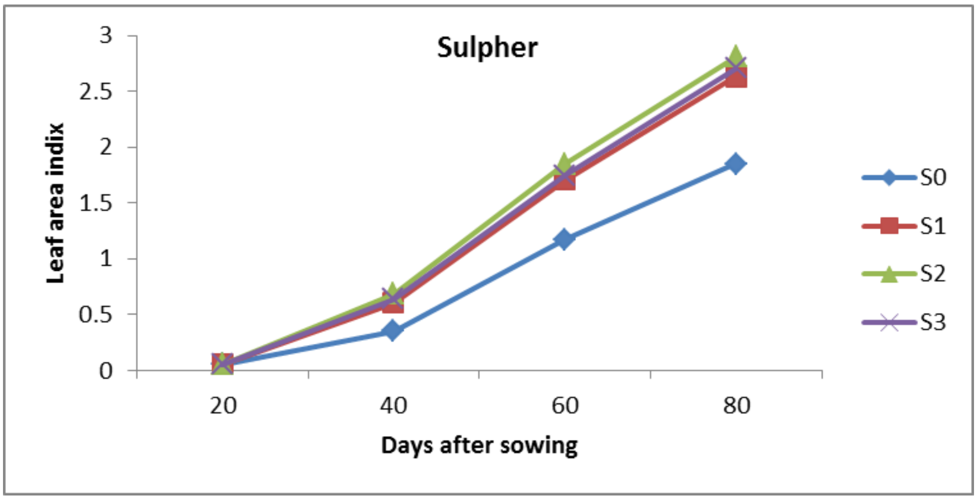


Figure 5. Effect of irrigation, sulpher and boron of leaf area index at different days after sowing (DAS) in 2012-2013





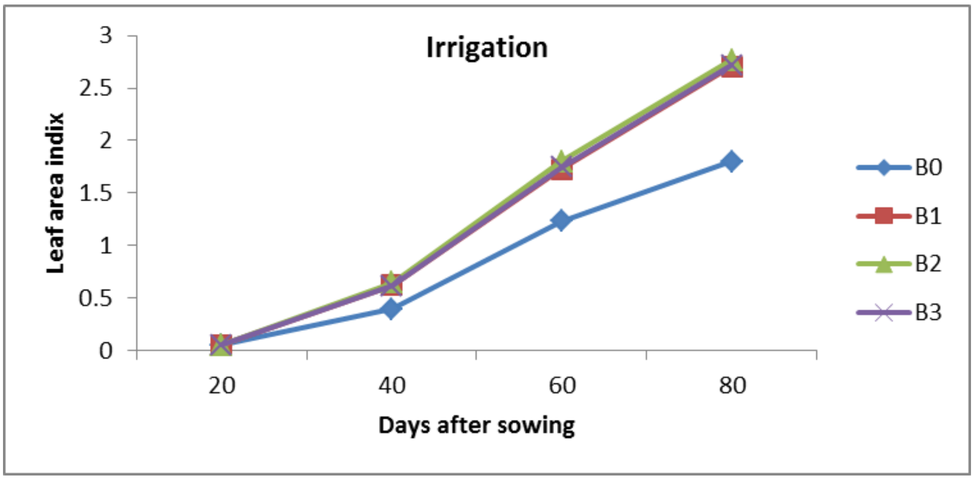


Figure 6. Effect of irrigation, sulpher and boron of leaf area index at different days after sowing (DAS) in 2013-2014

4.2.4. Net assimilation rate (NAR)

Irrigation levels had significant effect on NAR within the period of 20-40 and 60-80 DAS in 2012-2013 and 40-60 DAS in 2013-2014. During 20-40 DAS in 2012-2013, the highest NAR was obtained in I_2 treatment. Within the period of 60-80 DAS in 2012-2013, the highest NAR was obtained in I_2 treatment which was statistically identical with I_1 treatment. During 40-60 DAS in 2013-2014, the highest NAR was observed in I_1 treatment which was statistically identical with I_2 treatment. The lowest value was obtained in control in both the years (Table 31).

NAR was significantly influenced due to sulpher levels during the period of 20-40 and 60-80 DAS in both the years and 40-60 DAS (2013-2014) in both trails. During 20-40 DAS in 2012-2013, the highest NAR was obtained in S_2 treatment which was statistically similar to S_1 and S_3 treatments and in 2013-2014, the highest NAR was found in S_3 treatment which was statistically similar to S_1 and S_2 treatments. During 40-60 DAS in 2013-2014, the highest NAR was obtained in S_3 treatment which was statistically similar to S_2 treatment. Within the period of 60-80 DAS in 2012-2013, the highest NAR was obtained in S_2 treatment and in 2013-2014, the highest value was found in S_1 treatment which was statistically similar to S_2 and S_3 treatments. The lowest value was obtained in control in both the years (Table 32).

The different levels of boron had significant effect on NAR within the period of 20-40 and 40-60 in both the years and 60-80 DAS in 2013-2014. During 20-40 DAS in 2012-2013, the highest NAR was obtained from B_2 treatment and in 2013-2014, the highest NAR was found in B_1 treatment which was statistically similar to B_2 and B_3 treatments. Within the period of 40-60 DAS in 2012-2013, the highest NAR was observed from B_2 treatment which was statistically similar to B_1 and B_3 treatments and in 2013-2014, the highest NAR was found in B_1 treatment which was statistically similar to B_2 and B_3 treatments. The highest NAR was found in B_2 treatment during 60-80 DAS in 2013-2014. The lowest NAR was obtained in control in both the years (Table 33).

NAR was significantly influenced due to the interaction of irrigation and sulpher levels during 20-40 DAS in 2012-2013, 40-60 DAS in both trails and 60-80 DAS in 2013-2014. During 20-40 DAS in 2012-2013, the highest NAR was obtained from the treatment combination of I_1S_2 which was statistically similar to I_1S_1, I_1S_3, I_2S_2 and I_3S_2 treatment combinations. At 40-60 DAS in 2012-2013, the highest NAR was found in I_2S_2 combination which was identical with I_2S_1 and I_2S_3 treatment combinations and in 2013-2014, the highest value was obtained in I_1S_3 treatment combination. During 60-80 DAS in 2013-2014, I_2S_1 treatment combination gave the highest NAR which was statistically similar to I_2S_2 and I_2S_3 treatment combinations. The lowest NAR was obtained in control in both the years (Table 34).

The interaction between irrigation and boron levels had significant effect on NAR within the period of 20-40 DAS and 40-60 DAS in 2012-2013. During 20-40 DAS (2012-2013), the highest NAR was found in the treatment combination of I_1B_3 which was statistically similar to I_1B_1, I_1B_2 and I_2B_2 treatment combinations. Within the period of 40-60 DAS in 2012-2013, the highest NAR was observed from the treatment combination of I_2B_2 which was statistically similar to I_1B_1, I_1B_3, I_2B_1 and I_2B_3 treatment combinations. The lowest NAR was obtained in control in both years (Table 35).

NAR was significantly influenced by the interaction of sulpher and boron levels during the period of 20-40 in both the years. During the period of 20-40 DAS in 2012-2013, the highest NAR was obtained from S_2B_2 treatment combination which was statistically similar to S_2B_1, S_2B_3, S_1B_2, S_3B_1, S_3B_2 and S_3B_2 treatment combinations and in 2013-2014, the highest NAR was obtained from S_3B_2 treatment combination which was statistically similar to S_3B_1, S_3B_3 and S_1B_1 treatment combinations. The lowest NAR was obtained in control in both the years (Table 36).

Table 31. Effect of irrigation on net assimilation rate (mg cm^{-2} day^{-1}) at different days after sowing (DAS)

Irrigation	2012-2013			2013-2014		
	Net assimilation rate			Net assimilation rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
I_0	1.042b	8.742	4.858b	1.548	6.128b	5.269
I_1	1.204ab	8.431	6.286a	1.481	7.554a	4.798
I_2	1.375a	8.55	6.325a	1.531	7.269a	5.125
LS	0.01	NS	0.01	NS	0.01	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

Table 32. Effect of sulpher on net assimilation rate (mg cm^{-2} day^{-1}) at different days after sowing (DAS)

Sulpher	2012-2013			2013-2014		
	Net assimilation rate			Net assimilation rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
S_0	0.872b	8.231	5.120c	1.257b	6.128c	3.986b
S_1	1.176a	8.793	5.513bc	1.585a	6.923bc	5.529a
S_2	1.243a	8.623	6.510a	1.596a	7.422a	5.329a
S_3	1.221a	8.650	6.150ab	1.642a	7.462a	5.412a
LS	0.01	NS	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 33. Effect of boron on net assimilation rate (mg cm^{-2} day^{-1}) at different days after sowing (DAS)

Boron	2012-2013			2013-2014		
	Net assimilation rate			Net assimilation rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
B_0	0.926b	7.610b	5.673	1.301b	6.624b	4.763b
B_1	1.198ab	8.863a	6.068	1.611a	7.119a	5.158ab
B_2	1.220a	8.968a	5.677	1.586a	7.079a	5.275a
B_3	1.167ab	8.856a	5.874	1.582a	7.114a	5.059ab
LS	0.01	0.01	NS	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 34.Interaction effect of irrigation and sulpher on net assimilation rate (mg cm^{-2} day$^{-1)}$ at different days after sowing (DAS)

Interaction (I×S)	2012-2013			2013-2014		
	Net assimilation rate			Net assimilation rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
I_0 S_0	0.773d	7.551d	4.448	1.267	5.547g	4.784c
I_0 S_1	1.150ab	8.634b	4.533	1.600	6.139f	5.543ab
I_0 S_2	1.127ab	8.462bc	5.522	1.669	6.572de	5.380ab
I_0 S_3	1.118ab	8.321bcd	4.931	1.657	6.254f	5.369ab
I_1 S_0	0.957bcd	7.670cd	5.392	1.227	6.467cd	3.584d
I_1 S_1	1.270a	8.852ab	6.140	1.606	7.641b	5.339ab
I_1 S_2	1.311a	8.464bc	6.620	1.458	7.911ab	4.918bc
I_1 S_3	1.280a	8.736ab	6.993	1.633	8.198a	5.351ab
I_2 S_0	0.886cd	7.471d	5.433	1.277	6.370ef	3.589d
I_2 S_1	1.107abc	8.891a	5.952	1.550	6.991c	5.705a
I_2 S_2	1.291a	8.944a	7.387	1.660	7.783b	5.689a
I_2 S_3	1.266a	8.894a	6.526	1.637	7.934ab	5.517a
LS	0.01	0.01	NS	NS	0.05	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 35. Interaction effect of irrigation and boron on net assimilation rate (mg cm^{-2} day^{-1}) at different days after sowing (DAS)

Interaction (I×B)	2012-2013			2013-2014		
	Net assimilation rate			Net assimilation rate		
	20-40DAS	40-60DAS	60-80DAS	20-40 DAS	40-60 DAS	60-80 DAS
I_0 B_0	0.775d	7.902c	4.566	1.280	5.917	4.942
I_0 B_1	1.117abc	8.707b	4.688	1.676	6.111	5.408
I_0 B_2	1.146abc	8.638b	5.439	1.577	6.321	5.346
I_0 B_3	1.130abc	8.721b	4.741	1.660	6.162	5.379
I_1 B_0	1.026bc	7.541cd	6.507	1.329	7.125	4.661
I_1 B_1	1.258a	8.919a	6.012	1.525	7.636	4.923
I_1 B_2	1.261a	8.341b	6.078	1.561	7.517	5.039
I_1 B_3	1.272a	8.921a	6.548	1.508	7.941	4.569
I_2 B_0	0.977c	7.387d	6.259	1.294	6.829	4.688
I_2 B_1	1.219ab	8.964a	6.319	1.630	7.611	5.142
I_2 B_2	1.252a	8.925a	6.386	1.621	7.399	5.440
I_2 B_3	1.100abc	8.925a	6.334	1.579	7.239	5.229
LS	0.05	0.05	NS	NS	NS	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 36. Interaction effect of sulpher and boron on net assimilation rate (mg cm^{-2} day^{-1}) at different days after sowing(DAS)

Interaction (S×B)	2012-2013			2013-2014		
	Net assimilation rate			Net assimilation rate		
	20-40DAS	40-60DAS	60-80DAS	20-40DAS	40-60DAS	60-80DAS
S_0 B_0	0.627d	7.101	4.386	0.811f	5.850	3.472
S_0 B_1	0.930c	8.253	5.050	1.471bcd	6.284	4.205
S_0 B_2	0.973c	9.304	5.941	1.335de	6.015	4.141
S_0 B_3	0.957c	8.265	5.103	1.412cde	6.362	4.125
S_1 B_0	1.046bc	7.839	6.007	1.434cde	6.814	5.161
S_1 B_1	1.250ab	9.082	5.311	1.677a	7.028	5.676
S_1 B_2	1.306a	9.221	5.405	1.633ab	7.201	5.585
S_1 B_3	1.101abc	9.029	5.331	1.597e	6.651	5.693
S_2 B_0	1.029bc	7.894	6.672	1.518abcd	6.994	5.236
S_2 B_1	1.305a	8.980	6.063	1.593abc	7.530	5.235
S_2 B_2	1.325a	8.628	6.565	1.662ab	7.388	5.924
S_2 B_3	1.312a	8.991	6.739	1.610abc	7.776	4.921
S_3 B_0	1.002c	7.606	5.654	1.441cde	6.836	5.185
S_3 B_1	1.308a	9.138	6.269	1.701a	7.635	5.515
S_3 B_2	1.276a	8.719	6.351	1.715a	7.710	5.449
S_3 B_3	1.299a	9.139	6.324	1.712a	7.667	5.498
LS	0.05	NS	NS	0.05	NS	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant
LS=level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

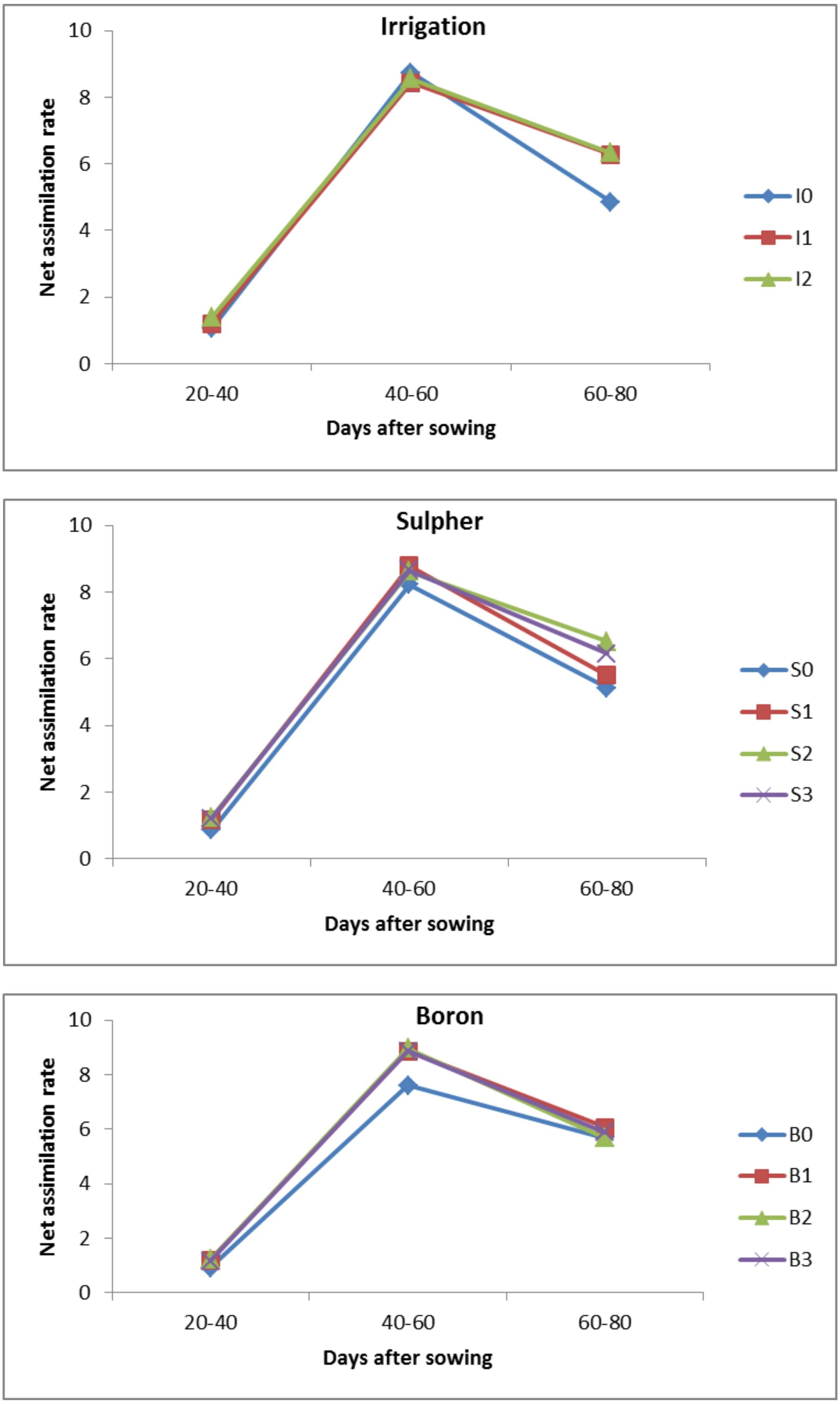


Figure 7. Effect of irrigation, sulpher and boron of net assimilation rate at different days after sowing (DAS) in 2012-2013

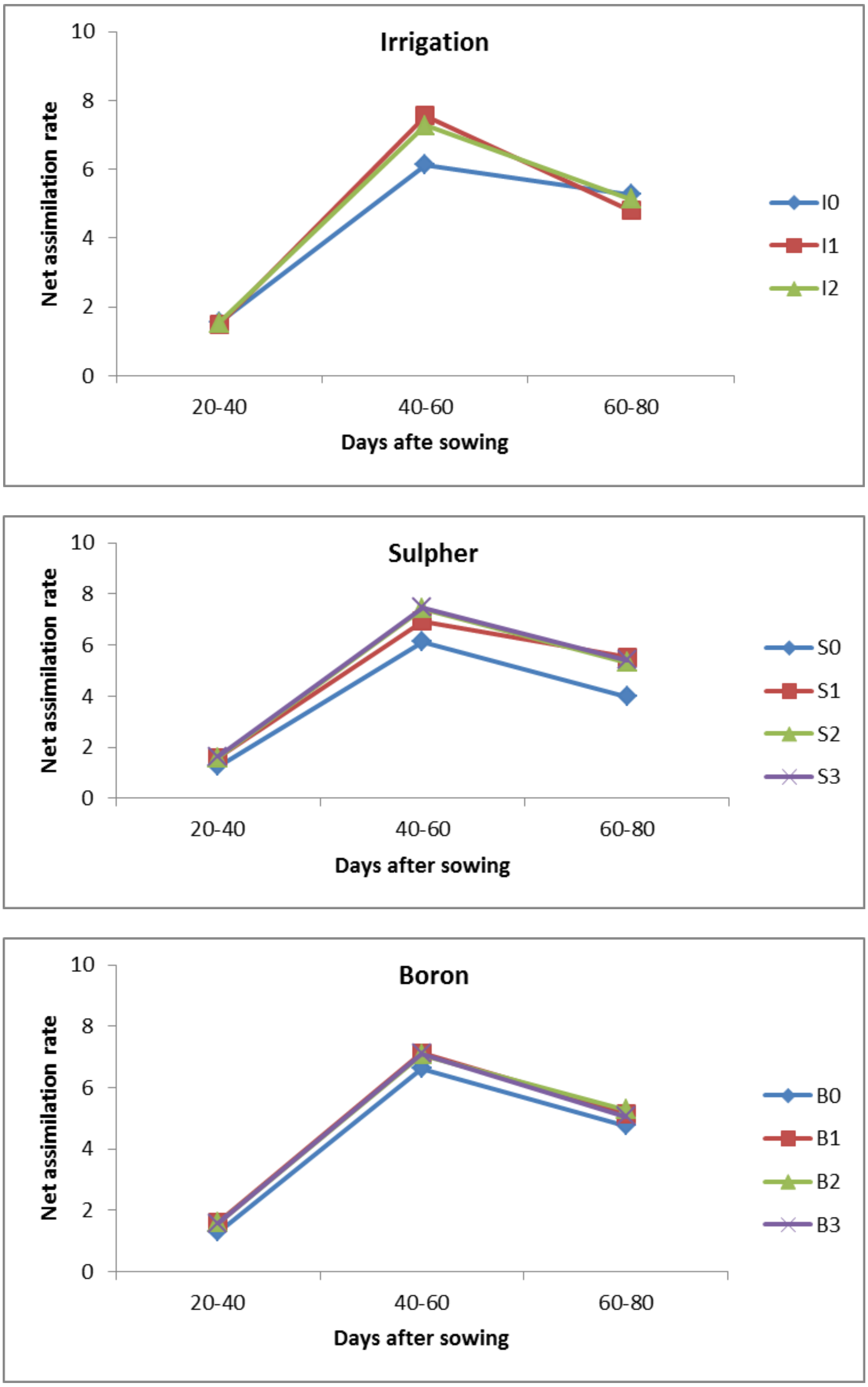


Figure 8. Effect of irrigation, sulpher and boron of net assimilation rate at different days after sowing (DAS) in 2013-2014

4.3. Yield and yield contributing characters

This chapter focuses with reports and results of the experiment. The experiment was aimed at studying the response of mustard as influenced by irrigation, sulphur and boron and their interaction. The data are presented in the tables. The results are interpreted under various sub-head such as number of branches, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, number of deformed seeds siliqua^{-1}, 1000-seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1})), biological yield (t ha^{-1}) and harvest index (%). In 2012-2013, results showed that yield and yield contributing characters i.e. number of branches, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, number of deformed seeds siliqua^{-1}, 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}) biological yield (t ha^{-1}) and harvest index (%) were significantly influenced due to irrigation, sulpher and boron levels. All yield and yield contributing characters number of siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000-seed weight (g), straw yield (t ha^{-1}) and biological yield (t ha^{-1}) studied were influenced due to the interaction of irrigation and sulpher. All yield and yield contributing characters except number of branches, number of deformed seeds, siliqua^{-1}, seed yield (t ha^{-1}) and biological yield (t ha^{-1}) studied were significantly influenced due to the interaction of irrigation and boron levels. Among all yield and yield contributing characters i.e. number of branches, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, seed yield (t ha^{-1}) straw yield (t ha^{-1}) and biological yield (t ha^{-1}) varied significantly influenced due to the interaction of sulpher and boron levels.

In 2013-2014, results showed that yield and yield contributing characters i.e. number of branches, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, number of deformed seeds siliqua^{-1}, 1000-seed weight (g), straw yield (t ha^{-1}) biological yield (t ha^{-1}) and harvest index (%) were significantly influenced due to irrigation, sulpher and boron levels. All yield and yield contributing characters number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1} and seed yield (t ha^{-1}) studied were influenced due to the interaction of irrigation and sulpher levels. All yield and yield contributing characters number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, seed yield (t ha^{-1}) and harvest index (%) studied were influenced due to the interaction of irrigation and boron levels. Among all yield and yield contributing characters i.e. number of branches, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, seed yield (t ha^{-1}), straw yield (t ha^{-1}) and biological yield (t ha^{-1}) varied significantly influenced due to the interaction of sulpher and boron levels.

The detailed experimental results have been presented in this chapter as given below:

4.3.1. Number of branches

The number of branches varied significantly due to irrigation levels in both the years. In 2012-2013 and 2013-2014, the highest number of branches was found in I_1 treatment which was statistically similar to I_2 treatment and the lowest value was obtained in control treatment (Table 37a and 37b).

The number of branches was significantly influenced by sulpher in both the years. The highest number of branches was obtained in S_2 treatment which was statistically similar to S_1 and S_3 treatments and lowest number of branches was observed in control (Table 38a and 38b).

Boron levels had significant effect on number of branches in both the trails. The highest number of branches was found in B_2 treatment which was statistically similar to B_1 and B_3 treatment and lowest number of branches was recorded in control (Table 39a and 39b).

The interaction of irrigation and sulpher levels had no significant effect on number of branches in both the years (Table 40a and 40b).

Number of branches did not show statistically significant variation by the interaction of irrigation and boron levels in both the years (Table 41a and 41b).

The interaction effect between sulpher and boron levels had significant effect on number of branches in both the years. The highest number of branches was obtained from S_2B_2 treatment combination and lowest value was observed from S_0B_0 treatment combination in both trails (Table 42a and 42b).

4.3.2. Number of siliqua plant^{-1}

It is observed that significantly the highest number of siliqua plant^{-1} was produced by I_1 treatment which was statistically similar to I_2 treatment in 2013-2014. The lowest number of siliqua plant^{-1} was produced in no irrigation in both trails (Table 37b).

In 2012-2013 and 2013-2014, different levels of sulphur application significantly influenced on the number of siliqua plant^{-1}. The highest number of siliqua plant^{-1} was recorded from S_3 treatment which was statistically similar to S_1 and S_2 treatments in 2012-2013 and in 2013-2014 the highest number of siliqua plant^{-1} was observed from S_2 treatment which was statistically similar to S_1 and S_3 treatments. The lowest value was found in control in both the years (Table 38a and 38b).

Number of siliqua plant^{-1} was significantly influenced due to boron levels in both the years. B_2 treatment gave the highest number of siliqua plant^{-1} which was statistically identical to B_1 and B_3 treatments in both trails. The lowest value was found in control in both the years (Table 39a and 39b).

The interaction between irrigation and sulpher levels did not show significant effect on number of siliqua plant^{-1} in 2012-2013. Significantly the highest number of siliqua plant^{-1} was recorded from I_1S_2 treatment combination and the lowest value was found in control in 2013-2014 (Table 40a and 40b).

The interaction effect between irrigation and boron levels had significantly influenced on the number of siliqua plant^{-1} in both the years. The highest number of siliqua plant^{-1} was obtained from I_1B_2 treatment combination in 2012-2013 and in 2013-2014, the highest number of siliqua plant^{-1} was found from I_1B_2 treatment combination which was statistically identical with I_1B_1 and I_1B_3 treatment combinations. The lowest value was observed from I_0B_0 treatment combination in both trails (Table 41a and 41b).

The interaction between sulpher and boron levels was found to be significant effect in respect of number of siliqua plant^{-1} in both the years. The highest number of siliqua plant^{-1} was found in S_2B_2 treatment combination which was statistically identical with S_2B_1, S_2B_3, S_3B_1, S_3B_2, and S_3B_3 treatment combinations in both trails. The lowest value was observed from S_0B_0 treatment combination in both trails. (Table 42a and 42b).

4.3.3. Siliqua length (cm)

Levels of irrigation significantly influenced on the siliqua length in both the years. The highest siliqua length was obtained from one irrigation at flowering stage which was statistically similar to two irrigations and the lowest siliqua length was obtained from when control treatment of irrigation was applied in both the years (Table 37a and 37b).

Siliqua length was affected significantly due to sulpher levels in both the years. S_2 treatment gave the highest siliqua length in 2012-2013 and in 2013-2014, the highest siliqua length was found in S_2 treatment. This result was statistically identical with S_1 and S_3 treatments in 2013-2014. The lowest value was found in control in both the years (Table 38a and 38b).

In 2012-2013 and 2013-2014, different levels of boron application significantly influenced on the siliqua length. The highest siliqua length was recorded from B_2 treatment which was statistically similar to B_1 and B_3 treatments in both the years. The lowest value was found in control in both the years (Table 39a and 39b).

The interaction between irrigation and sulpher levels showed significant effect on the siliqua length in 2012-2013 and 2013-2014. The highest siliqua length was recorded from I_1S_2 treatment combination and the lowest value was found in control in both trails (Table 40a and 40b).

Siliqua length had significantly influenced due to the interaction effect of irrigation and boron levels in both the years. The highest siliqua length was obtained from I_1B_2 treatment combination in 2012-2013 and in 2013-2014, the highest siliqua length was observed from I_1B_2 treatment combination. This result was statistically identical with I_1B_1, I_1B_3, I_2B_1,

I_2B_2 and I_2B_3 treatment combinations 2013-2014. The lowest value was observed from I_0B_0 treatment combination in both trails (Table 41a and 41b).

The interaction between sulpher and boron levels had significant effect on siliqua length in both trails. The highest siliqua length was observed from S_2B_2 treatment combination in 2012-2013 and 2013-2014. On other hand, the lowest siliqua length was recorded in control or S_0B_0 treatment combination (Table 42a and 42b).

4.3.4. No. of seeds siliqua^{-1}

The number of seeds siliqua^{-1} had differed significantly due to the irrigation levels in both the years. The highest number of seeds siliqua^{-1} was produced by one irrigation. The lowest number of seeds siliqua^{-1} was produced by no irrigation (Table 37a and 37b).

The application of 40 kg ha^{-1} sulphur produced the highest number of seeds siliqua^{-1} in both trails. The lowest seeds siliqua^{-1} was recorded from the control treatment in both the years (Table 38a and 38b).

Different levels of boron application significantly influenced on the number of seeds siliqua^{-1} in 2012-2013 and 2013-2014. The higher number of seeds siliqua^{-1} was obtained from 1.5 kg B ha^{-1} in both trails. The lowest seeds siliqua^{-1} was recorded from the control treatment (Table 39a and 39b).

The interaction of irrigation and sulpher levels showed significant effect on number of seeds siliqua^{-1} in 2012-2013 and 2013-2014. The highest number of seeds siliqua^{-1} was recorded from I_1S_2 treatment combination in both the years. This result was statistically identical with I_1S_1, I_1S_3, I_2S_1,

I_2S_2, and I_2S_3 treatment combinations in 2012-2013 and the lowest value was found in control in both trails (Table 40a and 40b).

Irrigation and boron levels had significant interaction effect on number of seeds siliqua^{-1} in both the trails. The highest number of seeds siliqua^{-1} was found in I_1B_2 treatment combination and lowest number of seeds siliqua^{-1} was recorded in control (Table 41a and 41b).

The interaction between sulpher and boron levels was found to be significant effect on number of seeds siliqua^{-1} in both the years. The highest number of siliqua plant^{-1} was found in S_2B_2 treatment combination which was statistically identical with S_1B_1, S_1B_2, S_1B_3, S_2B_1, S_2B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in both trails. The lowest value was observed from S_0B_0 treatment combination in both trails (Table 42a and 42b).

4.3.5. No. normal seeds siliqua^{-1}

The highest number of normal seeds siliqua^{-1} was observed in one irrigation and the lowest number of seeds siliqua^{-1} was observed from no irrigation in 2012-2013 and 2013-2014 (Table 37a and 37b).

The number of normal seeds siliqua^{-1} was significantly influenced by the sulphur application in both trails. The highest number of normal seeds siliqua^{-1} was produced in S_2 treatment in both the years. The number of normal seeds siliqua^{-1} was lowest with control treatment (Table 38a and 38b).

It has been observed that significantly the highest number of normal seeds siliqua^{-1} was produced by B_2 in 2012-2013 and 2013-2014. The lowest number of normal seeds siliqua^{-1} was produced in control (Table 39a and 39b).

The interaction between irrigation and sulpher levels showed significant effect on number of normal seeds siliqua^{-1} in 2012-2013 and 2013-2014. The highest number of normal seeds siliqua^{-1} was recorded from I_1S_2 combination treatment and the lowest value was found in control in 2012-2013 and 2013-2014 (Table 40a and 40b).

The number of normal seeds siliqua^{-1} had differed significantly due to the interaction effect of irrigation and boron levels in both years. The highest number of normal seeds siliqua^{-1} was obtained from I_1B_2 treatment combination in 2012-2013 and 2013-2014. The lowest value was observed from I_0B_0 treatment combination in both trails (Table 41a and 41b).

The interaction between sulpher and boron levels was found to be significant effect on number of normal seeds siliqua^{-1} in both the years. The highest number of number of normal seeds siliqua^{-1} was found in S_2B_2 treatment combination which was statistically identical with S_2B_1, S_2B_3, S_1B_1, S_1B_2, S_1B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in both trails. The lowest value was observed from S_0B_0 treatment combination in both trails (Table 42a and 48b).

4.3.6. No. of deformed seeds siliqua^{-1}

Two irrigation produced the lowest number of deformed seeds siliqua^{-1} and the highest number of deformed seeds siliqua^{-1} observed from control irrigation in both the years (Table 37a and 37b).

The application of 40 kg S ha^{-1} produced the lowest number of deformed seeds $siliqua^{-1}$ which was statistically different from other treatments and the highest number of deformed seeds $siliqua^{-1}$ was produced from control treatment in both trails (Table 38a and 38b).

The number of deformed seeds $siliqua^{-1}$ was significantly influenced by boron levels in both the years. The lowest number of deformed seeds $siliqua^{-1}$ was recorded when 1.5kg B ha^{-1} was applied; on the other hand the highest number of deformed seed $siliqua^{-1}$ was recorded when control treatment was applied (Table 39a and 39b).

The number of deformed seeds $siliqua^{-1}$ was no significantly influenced by the interaction effect of irrigation and sulpher in both trails (Table 40a and 40b).

The interaction effect between irrigation and boron levels had no significant variation in 2012-2013 and 2013-2014 (Table 41a and 41b).

The treatment combination of sulphur and boron levels showed no marked effect on the formation of deformed seeds $siluqua^{-1}$ in both the years (Table 42a and 42b).

4.3.7. 1000-seed weight (g)

From Table 37a and 37b, it can be seen that irrigation levels had significant effect on 1000-seed weight in 2012-2013 and 2013-2014. One irrigation levels produced the highest 1000-seed weight which was statistically similar with two irrigation levels and the lowest 1000-seed weight was produced by control treatment of irrigation in both the years.

Sulphur levels had significant effect on 1000- seed weight in both the years. The highest 1000- seed weight was produced by S_2 treatment which was statistically similar to S_1 and S_3 treatments in 2012-2013 and 2013-2014. The lowest 1000- seed weight was produced by control treatment (Table 38a and 38b).

The 1000-seed weight was significantly influenced by boron levels in both trails. The higher 1000- seed weight was recorded when 1.5 kg B ha^{-1} (B_2) was applied which was statistically similar to B_1 and B_3 treatment and lower 1000- seed weight was recorded in control in 2012-2013 and 2013-2014 (Table 39a and 39b).

Combination effect of irrigation and sulpher levels had significantly influenced on 1000-seed weight in 2012-2013. Maximum 1000-seed weight was recorded when I_1S_2 treatment combination was applied and the minimum 1000-seed weight was recorded in I_0S_0 treatment combination (Table 40a).

1000-seed weight was significantly influenced by the interaction effect of irrigation and boron in 2012-2013. The highest 1000-seed weight was found in I_1B_2 treatment combination and the lowest 1000-seed weight was found in the control treatment combination in 2012-2013 (Table 41a and 41b).

Combination effect of sulphur and boron levels had also significant effect on 1000-seed weight in both the years. Maximum 1000- seed weight was recorded when S_2B_2 treatment combination was applied and the lower 1000-seed weight was recorded in S_0B_0 treatment combination in 2012-2013 and 2013-2014 (Table 42a and 42b).

4.3.8. Seed yield (t ha^{-1})

It can be observed from table 37a and 37b, that the highest seed yield was produced by one irrigation levels and the significantly lowest seed yield was produced by control treatment of irrigation in both the years.

Sulpher levels showed significant variation in seed yield for both the years. Significantly the highest seed yield was recorded from S_2 treatment and the lowest was obtained in S_0 treatment in both trails (Table 38a and 38b).

The application of 1.5 kg B ha^{-1} produced the highest seed yield and the lowest seed yield was recorded from the control treatment in both the years (Table 39a and 39b).

Seed yield was significantly influenced by the interaction effect of irrigation and sulpher levels in 2013-2014. The highest seed yield was obtained from the interaction effect of I_1S_2 i.e. one irrigation levels with 40kg S ha^{-1} which was statistically similar to I_1S_3 and I_2S_2 treatment combination and the lowest seed yield was obtained from control treatment combination in 2013-2014 (Table 40a and 40b).

It was observed from table 41b, that the irrigation and boron interaction had significant effect on seed yield in 2013-2014. The maximum seed yield was recorded from the I_1B_2 treatment combination which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combinations and the minimum seed yield was recorded from I_0B_0 combination in 2013-2014.

Sulphur and boron interaction showed significant effect on seed yield in both the years. The highest seed yield was obtained from the treatment combination of S_2B_2 i.e. 40 kg S $ha^{-1}$with 1.5 kg B ha^{-1} in 2012-2013 and 2013-2014. The result was statistically similar to S_2B_1, S_2B_3, S_1B_1, S_1B_2,

S_1B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in 2012-2013. The lowest seed yield was produced by the treatment combination of the control treatment of sulphur and boron (S_0B_0) (Table 42a and 42b).

4.3.9. Straw yield (t ha^{-1})

The level of two irrigations produced significantly the highest straw yield which was statistically similar to one irrigation where control treatment of irrigation gave the lowest straw yield in both the years (Table 37a and 37b).

The effect of sulphur on straw yield of mustard was significant in both the years. The rate of 40 kg S ha^{-1} produced the highest straw yield where as control treatment gave the lowest straw yield in both the years (Table 38a and 38b).

Straw yield was significantly influenced by different levels of boron application in both trails. The maximum straw yield was observed when 2 kg B ha^{-1} was applied as basal dose which was statistically similar to other treatments and control gave lowest result (Table 39a and 39b).

The irrigation and sulpher interaction had significant effect on straw yield in 2012-2013. The highest straw yield was found in the treatment combination of I_2S_2 which was statistically similar to I_1S_2 and I_1S_3 treatment combinations while the lowest straw yield was found in the treatment of combination of I_0S_0 in 2012-2013 (Table 40a).

Straw yield was significantly influenced by the interaction effect of irrigation and boron levels in 2012-2013. The highest straw yield was obtained from I_1B_2 treatment combination which was statistically similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combinations and the lowest straw yield was obtained from I_0B_0 treatment combination in 2012-2013(Table 41a).

It was observed from table 42a and 42b, that the sulphur and boron interaction had significant effect on straw yield in both the years. The highest straw yield was found from the treatment combination of S_2B_2, while the lowest straw yield was obtained from the treatment of combination of S_0B_0 in both trails.

4.3.10. Biological yield (t ha^{-1})

From Table 37a and 37b, it can be seen that irrigation levels had significant effect on biological yield in 2012-2013 and 2013-2014. One irrigation levels produced the highest biological yield which was statistically identical with two irrigation levels and the lowest biological yield was produced by control treatment of irrigation in both the years.

Sulphur levels had significant effect on biological yield in both the years. The highest biological yield was produced by S_2 treatment in 2012-2013 and 2013-2014. This result was statistically similar to S_1 and S_3 treatments in 2013-2014. The lowest biological yield was produced by control treatment (Table 38a and 38b).

The biological yield was significantly influenced by boron levels in both trails. The higher biological yield was recorded when 1.5 kg B ha^{-1} (B_2) was applied which was statistically similar to B_1 and B_3 treatments and the lower biological yield was recorded in control in 2012-2013 and 2013-2014 (Table 39a and 39b).

Combination effect of irrigation and sulpher levels had significantly influenced on biological yield in 2012-2013. Maximum biological yield was recorded when I_1S_2 treatment combination was applied and the minimum biological yield was recorded in I_0S_0 treatment combination (Table 40a).

Biological yield was significantly influenced by the interaction effect of irrigation and boron in 2012-2013. The highest biological yield was found in I_1B_2 treatment combination which was similar to I_1B_1, I_1B_3, I_2B_1, I_2B_2 and I_2B_3 treatment combination and the lowest biological yield was found in the control treatment combination in 2012-2013 (Table 41a).

Combination effect of sulphur and boron levels had also significant effect on biological yield in both the years. Maximum biological yield was recorded when S_2B_2 treatment combination was applied which was statistically similar to S_2B_1 and S_2B_3 and the lower biological yield was recorded in S_0B_0 treatment combination in 2012-2013 and 2013-2014 (Table 42a and 42b).

4.3.11. Harvest index (%)

Two irrigations produced significantly the highest harvest index in 2012-2013 and 2013-2014. No irrigation gave the lowest harvest index (Table 37a and 37b).

The effect of sulphur on harvest index of mustard was significant in 2012-2013 and 2013-2014. The highest harvest index was found in S_2 treatment and S_0 treatment gave the lowest harvest index in 2012-2013 and 2013-2014 (Table 38a and 38b).

Harvest index was significantly influenced by different levels of boron application in 2012-2013 and 2013-2014. The maximum harvest index was observed in B_2 treatment and B_0 treatment gave the lowest result in 2012-2013 and 2013-2014 (Table 39a and 39b).

Harvest index was significantly influenced by the interaction effect of irrigation and boron levels in 2013-2014. The highest harvest index was obtained from I_1B_1 treatment combination and the lowest harvest index was obtained from I_0B_3 treatment combination in 2013-2014 (Table 41b).

Table 37a. Effect of irrigation on yield and yield contributing characters of mustard (2012-2013)

Irrigation	Number of branches	Number of siliqua plant^{-1}	Siliqua length (cm)	Number of seed siliqua^{-1}	Number of normal seed siliqua^{-1}	Number of deformed seed siliqua^{-1}	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0	20.335b	126.125	3.896b	14.015b	11.617b	2.397a	3.369b	1.597c	2.704b	4.301b	37.140c
I_1	25.343a	145.513	4.416a	16.102a	13.909a	2.194b	3.846a	2.260a	2.939a	5.229a	43.221a
I_2	24.550a	139.032	4.279a	14.587ab	12.569ab	2.017c	3.748a	2.021b	3.048a	5.090a	39.705b
LS	0.05	NS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS= Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

Table 37b. Effect of irrigation on yield and yield contributing characters of mustard (2013-2014)

Irrigation	Number of branches	Number of siliqua^{-1} plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0	19.860b	121.378b	3.795b	13.504b	11.143b	2.361a	3.041b	1.526c	2.813b	4.343b	35.308c
I_1	24.706a	140.131a	5.094a	15.402a	13.272a	2.130a	3.387a	2.100a	2.933a	5.046a	41.617a
I_2	23.967a	134.173a	4.763a	13.945ab	11.986ab	1.959b	3.343a	1.846b	3.092a	4.960a	37.317b
LS	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant. I_0 = Control
LS= Level of significant I_1 = One irrigation
I_2 = Two irrigations

Table 38a. Effect of sulpher on yield and yield contributing character of mustards (2012-2013)

Sulpher	Number of branches	Number of siliqua plant^{-1}	Siliqua length (cm)	Number of seed siliqua^{-1}	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0	17.016b	112.614b	2.991b	11.853c	3.312c	2.540a	2.790b	1.262c	2.234b	3.496c	36.098c
S_1	24.499a	138.084a	4.431a	15.193b	13.009b	2.185ab	3.776a	1.839b	3.204ab	5.044b	36.459c
S_2	26.889a	134.339a	4.793a	16.692a	14.812a	1.880b	4.133a	2.221a	3.345a	5.633a	39.428a
S_3	25.233a	146.522a	4.573a	15.534ab	13.327ab	2.206ab	3.918a	1.915b	3.206ab	5.121b	37.395b
LS	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS= Level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 38b.Effect of sulpher on yield and yield contributing characters of mustard (2013-2014)

Sulpher	Number of branches	Number of siliqua^{-1} plant	Siliqua length (cm)	Number of seed^{-1} siliqua	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0	16.669b	108.337b	2.780c	11.471b	8.965b	2.506a	2.342b	1.249c	2.167b	3.614b	34.560c
S_1	23.912a	132.836a	4.826b	14.548ab	12.422ab	2.126ab	3.417a	1.820b	3.161a	4.830a	37.681b
S_2	26.206a	145.328a	5.467a	15.955a	14.129a	1.827b	3.781a	2.221a	3.297a	5.501a	40.374a
S_3	24.592a	141.074a	5.130ab	14.828ab	12.686ab	2.142ab	3.488a	1.938b	3.226a	5.187a	37.363b
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS= Level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 39a. Effect of boron on yield and yield contributing characters of mustard (2012-2013)

Boron	Number of branches	Number of siliqua plant^{-1}	Siliqua length (cm)	Number of seed siliqua^{-1}	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
B_0	18.507b	119.833b	3.057b	11.958b	9.484b	2.474a	2.857b	1.307c	2.173b	3.679b	35.526c
B_1	24.907a	141.857a	3.501a	15.281ab	13.119ab	2.162b	3.854a	2.074b	3.089a	5.203a	39.862b
B_2	25.232a	144.328a	4.709a	16.734a	14.661a	2.074b	4.034a	2.266a	3.079a	5.345a	42.395a
B_3	24.990a	142.117a	4.520a	15.298ab	13.197ab	2.101b	3.873a	2.090b	3.148a	5.265a	39.696b
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 39b. Effect of boron on yield and yield contributing characters of mustard (2013-2014)

Boron	Number of branches	Number of siliqua plant^{-1}	Siliqua length (cm)	Number of seed siliqua^{-1}	Number of normal seed siliqua^{-1}	Number of deformed seed siliqua^{-1}	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
B_0	18.109b	115.417b	3.180b	11.521b	9.086b	2.434a	2.458b	1.331c	2.274b	4.396b	30.278c
B_1	24.289a	136.525a	4.944a	14.616ab	12.501ab	2.116b	3.457a	1.870b	3.198a	4.631a	40.380a
B_2	24.590a	138.906a	5.143a	16.027a	14.018a	2.009b	3.624a	2.123a	3.152a	5.135a	41.344a
B_3	24.390a	136.726a	4.935a	14.638ab	12.597ab	2.041b	3.489a	1.905b	3.228a	4.971a	38.322b
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 40a. Interaction effect of irrigation and sulpher on yield and yield contributing characters of mustard (2012-2013)

Interaction (I×S)	Number of branches	Number of siliqua^{-1} plant	Siliqua length (cm)	Number of seed^{-1} siliqua	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0 S_0	12.951	108.035	2.805e	12.231cd	9.507d	2.724	2.638e	1.363	1.778f	3.152h	43.189
I_0 S_1	22.212	127.848	4.159d	14.487bc	12.094c	2.393	3.514d	1.901	2.617d	4.518f	42.213
I_0 S_2	23.471	134.973	4.355bcd	14.391bc	12.379bc	2.012	3.704bcd	1.983	2.867cd	4.849ef	41.032
I_0 S_3	22.705	133.643	4.266cd	14.949ab	12.489bc	2.460	3.618cd	1.940	2.744d	4.684f	41.575
I_1 S_0	19.364	114.581	3.108c	11.835b	9.248d	2.587	2.816e	1.490	2.187e	3.677g	40.828
I_1 S_1	25.937	145.443	4.611bcd	15.621ab	13.555abc	2.066	3.950bcd	2.132	3.256ab	5.390cd	39.752
I_1 S_2	29.046	166.977	5.180a	16.898a	14.932a	2.057	4.516a	2.384	3.576a	6.078a	39.420
I_1 S_3	27.025	155.051	4.765abc	15.964ab	13.899abc	2.065	4.103ab	2.234	3.538a	5.772abc	38.934
I_2 S_0	18.733	115.226	3.058c	11.492d	9.182d	2.310	2.917e	1.534	2.126ef	3.658g	41.932
I_2 S_1	25.346	140.960	4.524bcd	15.472ab	13.377abc	2.096	3.862bcd	2.084	3.140bc	5.224de	40.031
I_2 S_2	28.150	150.798	4.844ab	15.694ab	14.125ab	1.569	4.180ab	2.296	3.592a	5.971ab	39.899
I_2 S_3	25.970	150.873	4.688abcd	15.688ab	13.593abc	2.094	4.033bc	2.1714	3.335ab	5.506bcd	39.910
LS	NS	NS	0.05	0.01	0.01	NS	0.01	NS	0.01	0.01	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 40b. Interaction effect irrigation and sulpher on yield and yield contributing characters of mustard (2013-2014)

Interaction (I×S)	Number of branches	Number of siliqua $^{-1}$ plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0S_0	12.666	104.004f	2.280g	11.917bc	9.222c	2.696	2.230	1.105f	2.063	3.305	34.777
I_0S_1	21.681	122.988de	4.248de	13.903ab	11.563b	2.339	3.267	1.592d	3.022	4.514	35.481
I_0S_2	22.915	129.863cd	4.449de	13.826ab	11.823b	2.003	3.356	1.739cd	3.104	4.835	35.969
I_0S_3	22.180	128.656cd	4.203e	14.371ab	11.964b	2.408	3.313	1.667d	3.065	4.717	35.005
I_1S_0	18.968	110.151ef	3.167f	11.400c	8.852c	2.547	2.428	1.340e	2.246	3.804	37.341
I_1S_1	25.268	139.944bcd	5.357bc	14.884a	12.885ab	1.999	3.508	1.968ab	2.245	5.049	39.499
I_1S_2	28.279	161.157a	6.138a	16.145a	14.164a	1.981	4.020	2.157a	3.718	5.800	37.409
I_1S_3	26.311	149.270ab	5.713ab	15.179a	13.185ab	1.994	3.591	2.134a	3.322	5.533	39.016
I_2S_0	18.787	110.856ef	2.893fg	11.095c	8.821c	2.274	2.368	1.304ef	2.191	3.733	36.397
I_2S_1	24.787	135.577bcd	4.873cd	14.858a	12.818ab	2.040	3.477	1.900bc	3.216	4.928	38.868
I_2S_2	27.423	144.963abc	5.814ab	14.895a	13.398ab	1.496	3.966	2.066a	3.669	5.868	37.086
I_2S_3	25.286	145.295ab	5.473bc	14.935a	12.909ab	2.026	3.560	2.015ab	3.293	5.310	36.919
LS	NS	0.05	0.01	0.01	0.01	NS	NS	0.01	NS	NS	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 41a. Interaction effect of irrigation and boron on yield and yield contributing characters of mustard (2012-2013)

Interaction (I×B)	Number of branches	Number of siliqua $^{-1}$ plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed $^{-1}$ siliqua	Number of deformed seed $^{-1}$ siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0 B_0	15.472	117.864de	2.830d	11.734c	9.061d	2.673	2.623f	1.348	1.908d	3.256d	41.718
I_0 B_1	21.859	129.273de	4.200c	14.568b	12.185c	2.383	3.565d	1.905	2.684b	4.589b	41.693
I_0 B_2	22.079	130.435cde	4.332bc	15.254ab	13.015bc	2.239	3.698bcd	2.015	2.719b	4.734b	42.693
I_0 B_3	21.929	126.927de	4.223c	14.502b	12.208c	2.294	3.588cd	1.919	2.704b	4.623b	41.692
I_1 B_0	20.404	120.473de	3.193d	12.194c	9.808d	2.386	2.883ef	1.603	2.367bc	3.969c	40.720
I_1 B_1	26.779	152.331abc	4.694ab	15.769ab	13.648ab	2.121	4.037ab	2.191	3.286a	5.596a	39.426
I_1 B_2	27.314	155.418a	5.064a	16.548a	14.412a	2.136	4.409a	2.238	3.480a	5.718a	39.364
I_1 B_3	26.875	153.830ab	4.713ab	15.898ab	13.765ab	2.132	4.056ab	2.209	3.424a	5.633a	39.444
I_2 B_0	19.645	121.163c	3.148d	11.946c	9.582d	2.363	3.064e	1.572	2.243cd	3.813c	41.552
I_2 B_1	26.083	143.968ab	4.610bc	15.506ab	13.523ab	1.982	3.959bcd	2.127	3.297a	5.425a	39.465
I_2 B_2	26.304	147.131ab	4.731ab	15.400ab	13.554ab	1.546	3.996b	2.245	3.337a	5.582a	40.581
I_2 B_3	26.167	145.593ab	4.625bc	15.495ab	13.617ab	1.877	3.973bc	2.141	3.315a	5.400a	40.176
LS	NS	0.01	0.01	0.05	0.05	NS	0.01	NS	0.01	0.05	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha

Table 41b. Interaction effect of irrigation and boron on yield and yield contributing of mustard (2013-2014)

Interaction (I×B)	Number of branches	Number of siliqua $^{-1}$ plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed $^{-1}$ siliqua	Number of deformed seed $^{-1}$ siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$I_0 B_0$	15.150	113.713c	2.573e	11.380c	8.739d	2.641	2.300	1.175d	2.128	3.965	36.225ab
$I_0 B_1$	21.351	124.345bc	4.063bc	14.055b	11.677c	2.378	3.275	1.632b	3.030	4.275	38.434abc
$I_0 B_2$	21.526	125.473bc	4.425b	14.646ab	12.693bc	2.184	3.303	1.652b	3.056	4.693	35.043bc
$I_0 B_3$	21.414	121.980bc	4.119bc	13.936b	11.693c	2.243	3.287	1.644b	3.040	4.438	31.530c
$I_1 B_0$	19.963	115.862c	3.527cd	11.709c	9.368d	2.342	2.547	1.445bc	2.356	4.727	37.874abc
$I_1 B_1$	26.084	146.802a	5.559a	15.005ab	12.953ab	2.051	3.593	1.986a	3.323	4.775	43.344a
$I_1 B_2$	26.605	149.695a	5.675a	15.768a	13.703a	2.065	3.796	2.100a	3.511	5.426	38.400abc
$I_1 B_3$	26.173	148.163a	5.615a	15.126ab	13.063ab	2.062	3.612	2.067a	3.341	5.258	33.647c
$I_2 B_0$	19.215	116.677c	3.440d	11.473c	9.153d	2.320	2.528	1.373cd	2.339	4.495	36.384bc
$I_2 B_1$	25.432	138.428ab	5.212a	14.789ab	12.872ab	1.917	3.502	1.993a	3.239	4.842	41.451ab
$I_2 B_2$	25.638	141.551ab	5.331a	14.667ab	12.888ab	1.779	3.772	2.016a	3.489	5.287	36.855abc
$I_2 B_3$	25.583	140.035ab	5.070a	14.853ab	13.034ab	1.819	3.569	2.003a	3.302	5.216	34.580ab
LS	NS	0.01	0.01	0.05	0.05	NS	NS	0.01	NS	NS	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0= 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2= 1.5 kg B ha^{-1}
B_3 = 2 kg B ha

Table 42a. Interaction effect of sulpher and boron on yield and yield contributing character of mustards (2012-2013)

Interaction (S×B)	Number of branches	Number of siliqua $^{-1}$ plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed $^{-1}$ siliqua	Number of deformed seed $^{-1}$ siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0B_0	11.684g	109.609d	2.461d	10.251c	7.460c	2.791	2.430d	1.224c	1.677d	2.898e	42.573ab
S_0B_1	18.650f	112.954c	3.049c	12.167b	9.681b	2.486	2.828c	1.457bc	2.139c	3.596d	40.775ab
S_0B_2	18.969ef	114.254c	3.400c	12.828b	10.418b	2.410	3.071c	1.703b	2.164c	3.867cd	43.837a
S_0B_3	18.761ef	113.638c	3.052c	12.166b	9.691b	2.474	2.831c	1.466bc	2.156c	3.622cd	40.746ab
S_1B_0	20.678de	120.104c	3.200c	12.492b	10.073b	2.419	2.947c	1.559bc	2.315c	3.874cd	40.530ab
S_1B_1	25.700c	142.416ab	4.816b	16.112a	13.927a	2.186	4.026b	2.186a	3.210b	3.874b	40.766ab
S_1B_2	25.850c	145.671ab	4.868b	16.040a	13.978a	2.062	4.078b	2.213a	3.260b	5.397b	40.661ab
S_1B_3	25.767c	144.143ab	4.842b	16.129a	14.057a	2.072	4.052b	2.198a	3.232b	5.430b	40.704ab
S_2B_0	21.456d	121.660c	3.324c	12.554b	10.352b	2.202	3.056c	1.647b	2.446c	4.092c	40.483ab
S_2B_1	28.467ab	158.699a	5.149ab	16.320a	14.656a	1.664	4.359ab	2.387a	3.520ab	6.064a	39.572b
S_2B_2	29.061a	162.571a	5.528a	17.416a	15.548a	1.869	4.738a	2.440a	3.717a	6.157a	39.812b
S_2B_3	28.572ab	160.732a	5.171ab	16.4476a	14.692a	1.783	4.381ab	2.410a	3.696a	6.107a	40.601ab
S_3B_0	20.210ef	127.960bc	3.243c	12.534b	10.050b	2.484	2.996c	1.599b	2.254c	3.853cd	41.733ab
S_3B_1	26.812bc	153.360a	4.992b	16.524a	14.212a	2.312	4.202b	2.269a	3.487ab	5.756ab	39.663b
S_3B_2	27.050bc	154.816a	5.040b	16.652a	14.699a	1.954	4.250b	2.307a	3.574ab	5.880ab	39.464b
S_3B_3	26.861bc	149.816a	5.016b	16.423a	14.348a	2.076	4.226b	2.286a	3.507ab	5.793ab	39.699b
LS	0.05	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.01	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS = Level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0 = 0 kg B_0 ha^{-1}
B_1 = 1 kg B_1 ha^{-1}
B_2 = 1.5 kg B_2 ha^{-1}
B_3 = 2 kg B_3 ha^{-1}

Table 42b. Interaction effect of sulpher and boron on yield and yield contributing characters of mustard (2013-2014)

Interaction (S×B)	Number of branches	Number of siliqua $^{-1}$ plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed^{-1} siliqua	Number of deformed seed^{-1} siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0B_0	11.423f	105.689c	2.089f	9.964c	7.199c	2.765	1.947d	1.039e	1.801d	3.851cde	31.708
S_0B_1	18.284e	108.572c	2.924g	11.765bc	9.316b	2.449	2.460cd	1.312d	2.276cd	3.331e	39.417
S_0B_2	18.582e	109.847c	3.093de	12.402b	10.031b	2.371	2.489cd	1.326d	2.302cd	3.612de	36.559
S_0B_3	18.384e	109.239c	3.013de	11.751bc	9.314b	2.437	2.473cd	1.321d	2.288cd	3.662de	37.004
S_1B_0	20.252de	115.546c	3.404de	12.024b	9.648b	2.376	2.587c	1.415d	2.393c	3.985b-e	41.085
S_1B_1	25.038c	136.963ab	5.293c	15.384a	13.265a	2.119	3.674b	1.941c	3.398b	4.807a-d	40.765
S_1B_2	25.159c	140.168ab	5.531bc	15.280a	13.286a	1.993	3.702b	1.971bc	3.424b	5.371a	36.425
S_1B_3	25.199c	138.668ab	5.074c	15.505a	13.489a	2.016	3.706b	1.954c	3.428b	5.159abc	33.522
S_2B_0	20.998d	116.971c	3.662d	12.051b	9.894b	2.156	2.667c	1.491d	2.467c	4.878a-d	38.589
S_2B_1	27.721ab	152.935a	5.965ab	15.562a	13.910a	1.652	3.938ab	2.124abc	3.642ab	5.338a	41.985
S_2B_2	28.822a	156.611a	6.237a	16.559a	14.768a	1.791	4.513a	2.240a	4.175a	5.920a	36.148
S_2B_3	27.822ab	154.793a	6.003ab	15.650a	13.942a	1.708	4.005a	2.227ab	3.705ab	5.867a	30.563
S_3B_0	19.764de	123.463bc	3.564de	12.044b	9.604b	2.440	2.633c	1.379d	2.436c	4.868a-d	35.928
S_3B_1	26.113bc	147.630a	5.564abc	15.755a	13.513a	2.242	3.755b	2.104abc	3.473b	5.046abc	42.137
S_3B_2	26.336abc	148.999a	5.712abc	15.867a	13.985a	1.882	3.791b	2.155abc	3.506b	5.638a	37.933
S_3B_3	26.155bc	144.203a	5.648abc	15.647a	13.642a	2.005	3.773b	2.116abc	3.490b	5.195ab	31.921
LS	0.05	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.05	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS = Level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0 = 0 kg B_0 ha^{-1}
B_1 = 1 kg B_1 ha^{-1}
B_2 = 1.5 kg B_2 ha^{-1}
B_3 = 2 kg B_3 ha

4.3.12. Association between yield and yield contributing characters

Sample correlation coefficients between yield and yield components of mustard are shown in (Table 43 and 44.)

In 2012-2013, number of branches was positively correlated with number of siliqua plant^{-1}, siliqua length(cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of seeds siliqua^{-1} was positively correlated with siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000-seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Siliqua length (cm) was positively correlated with number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000-seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of seeds siliqua^{-1} was positively correlated with number of normal seeds siliqua^{-1}, 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of normal seeds siliqua^{-1} was positively correlated with 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of deformed seeds siliqua^{-1} was negatively correlated with 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). 1000-seed weight (g) was positively correlated with seed yield (t ha^{-1}), straw yield (t ha^{-1}). Seed yield (t ha^{-1}) was positively correlated with straw yield (t ha^{-1}). In the field experiment Haque (2000) observed significantly positive correlation of pods plant^{-1} and seeds siliqua^{-1} with seed yield.

In 2013-2014, number of branches was positively correlated with number of siliqua plant^{-1}, siliqua length(cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of seeds siliqua^{-1} was positively correlated with siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000-seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Siliqua length (cm) was positively correlated with number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of seeds siliqua^{-1} was positively correlated with number of normal seeds siliqua^{-1}, 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of normal seeds siliqua^{-1} was positively correlated with 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). Number of deformed seeds siliqua^{-1} was negatively correlated with 1000- seed weight (g), seed yield (t ha^{-1}), straw yield (t ha^{-1}). 1000-seed weight (g) was positively correlated with seed yield (t ha^{-1}), straw yield (t ha^{-1}). Seed yield (t ha^{-1}) was positively correlated with straw yield (t ha^{-1}). In the field experiment Haque (2000) observed significantly positive correlation of pods plant^{-1} and seeds siliqua^{-1} with seed yield.

Table 43. Simple correlation coefficient between yield and yield components of mustard diagonal shows values in 2012-2013

Variable	Number of branches	Number of siliqua $plant^{-1}$	Siliqua length (cm)	Number of seed $siliqua^{-1}$	Number of normal $seed^{-1}$ siliqua	Number of deformed $seed^{-1}$ siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
Number of branches									
Number of siliqua $plant^{-1}$	0.762**								
Siliqua length (cm)	0.852**	0.883**							
Number of seed $siliqua^{-1}$	0.767**	0.803**	0.816**						
Number of normal $seed^{-1}$ siliqua	0.814**	0.840**	0.867**	0.980**					
Number of deformed $seed^{-1}$ siliqua	-0.599**	-0.551**	-0.613**	-0.390**	-0.540**				
1000-seed weight (g)	0.767**	0.746**	0.858**	0.772**	0.818**	-0.579**			
Seed yield (t ha^{-1})	0.628**	0.625**	0.661**	0.486**	0.537**	-0.461**	0.541**		
Straw yield (t ha^{-1})	0.628**	0.627**	0.653**	0.520**	0.563**	-0.461**	0.951**	0.815**	

**Correlation is significant at the 0.01 level (2-trailed)

Table 44. Simple correlation coefficient between yield and yield components of mustard diagonal shows values in 2013-2014.

Variable	Number of branches	Number of siliqua $^{-1}$ plant	Siliqua length (cm)	Number of seed $^{-1}$ siliqua	Number of normal seed $^{-1}$ siliqua	Number of deformed seed $^{-1}$ siliqua	1000-seed weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
Number of branches									
Number of siliqua $^{-1}$ plant	0.804**								
Siliqua length (cm)	0.844**	0.871**							
Number of seed $^{-1}$ siliqua	0.826**	0.829**	0.865**						
Number of normal seed $^{-1}$ siliqua	0.860**	0.853**	0.893**	0.988**					
Number of deformed seed $^{-1}$ siliqua	-0.590**	-0.540**	-0.574**	-0.405**	-0.542**				
1000-seed weight (g)	0.816**	0.866**	0.971**	0.826**	0.855**	-0.564**			
Seed yield (t ha^{-1})	0.815**	0.836**	0.876**	0.865**	0.896**	-0.593**	0.824**		
Straw yield (t ha^{-1})	0.832**	0.875**	0.948**	0.763**	0.805**	-0.608**	0.951**	0.815**	

**Correlation is significant at the 0.01 level (2-trailed)

4.4. Quality of mustard

4.4.1. Moisture content (%)

Irrigation levels had significant effect in moisture content (%) in seed in both the years. The highest moisture content (%) in seed was found in I_1 treatment which was identical with I_2 treatment and the lowest moisture content (%) was obtained from control in both trails (Table 45).

Moisture content (%) in seed differed significantly due to irrigation levels in both trails. Higher moisture content (%) was recorded in S_2 treatment in both the years. This was followed S_1 and S_3 treatments in 2012-2013. The lowest moisture content (%) was observed from S_0 treatment (Table 46).

The effect of boron levels was found to be significant effect on moisture content (%) in both the years. The highest moisture content (%) was found in B_2 treatment which was identical with B_1 and B_3 treatment in both trails. The lowest moisture content (%) was observed from B_0 treatment (Table 47).

The interaction effect between irrigation and sulpher was statistically significant on moisture content (%) in seed in both the years. In 2012-2013 and 2013-2014, the highest moisture content (%) was observed from I_1S_2 treatment combination and the lowest moisture content (%) was found in control treatment combination (Table 48).

Moisture content (%) in seed varied significantly due to the interaction of irrigation and boron levels in both trails. The highest moisture content (%) was obtained from I_1B_2 treatment combination and the lowest value was found in I_0B_0 treatment combination in 2012-2013 and 2013-2014 (Table 49).

The interaction effect of sulpher and boron was statistically significant on moisture content (%) in seed in both the years. In 2012-2013 and 2013-2014, the highest moisture content (%) was observed from S_2B_2 treatment combination and the lowest moisture content (%) was found in control treatment combination (Table 50).

4.4.2. Oil content (%)

Oil content (%) was significantly influenced by the effect of irrigation levels in both the years. The highest oil content (%) was found in one irrigation levels which was statistically similar with two irrigations and the lowest value was obtained from control in both the years (Table 45).

The effect of sulpher levels had significant effect on oil content (%) in both the years. Results showed that S_2 treatment produced the highest oil content (%) in both trails. This was statistically similar to S_1 and S_3 treatments in 2013-2014. The lowest value was obtained from S_0 treatment (Table 46).

Boron levels had significant effect on oil content (%) in both trails. The highest oil content (%) was found in B_2 treatment in both the years which was identically similar to B_1 and B_3 treatments and the lowest value was obtained in B_0 treatment in 2012-2013 and 2013-2014 (Table 47).

The interaction effect of irrigation and sulpher levels was found to be significant effect on oil content (%) in 2013-2014. Results showed that I_1S_2 treatment combination produced the highest oil content (%) and the lowest value was obtained in I_0S_0 treatment combination in 2013-2014 (Table 48).

Oil content (%) in seed varied significantly due to the interaction of irrigation and boron levels in 2013-2014. The highest oil content (%) was observed in I_1B_2 treatment combination which was identically similar with I_1B_3 treatment combination and the lowest value was obtained in I_0B_0 treatment combination in 2013-2014 (Table 49).

The interaction between sulpher and boron levels had significant effect on oil content (%) in both the years. Significantly highest oil content (%) was recorded in S_2B_2 treatment combination which was statistically similar to S_2B_1 S_2B_3 treatment combinations and the lowest was found in S_0B_0 treatment combination in both trails (Table 50).

4.4.3. Protein content (%)

Protein content (%) was significantly influenced by the effect of irrigation levels in both the years. The highest protein content (%) was found in one irrigation levels which was statistically similar to two irrigations and the lowest value was obtained from control in both the years (Table 45).

The effect of sulpher levels had significant effect on protein content (%) in both the years. Results showed that S_2 treatment produced the highest protein content (%) in both trails. This was statistically similar to S_1 and S_3 treatments in 2012-2013 and 2013-2014. The lowest value was obtained from S_0 treatment (Table 46).

Boron levels had significant effect on protein content (%) in both trails. The highest oil content (%) was found in B_2 treatment in both the years which was identically similar to B_1 and B_3 treatments and the lowest value was obtained in B_0 treatment in 2013 and 2014 (Table 47).

The interaction between irrigation and sulpher levels had no significant effect on protein content (%) in both the years (Table 48).

The interaction effect of irrigation and boron levels was found to be significant effect on protein content (%) in 2012-2013 and 2013-2014. Results showed that I_1S_2 treatment combination produced the highest protein content (%) which was identically similar to I_1B_1, I_1B_3 in 2012-2013 and in 2013-2014, I_1B_1, I_1B_3, I_2B_1, I_2B_3 and I_2B_3 treatment combinations and the lowest value was obtained in I_0B_0 treatment combination in 2012-2013 and 2013-2014 (Table 49).

Protein content (%) varied significantly due to the interaction of irrigation and boron in 2012-2013 and 2013-2014. The highest protein content (%) was observed in S_2B_2 treatment combination in both the years. This result was identically similar to S_2B_1, S_2B_3 S_1B_1, S_1B_2, S_1B_3, S_3B_1, S_3B_2 and S_3B_3 treatment combinations in 2012-2013. The lowest value was obtained in S_0B_0 treatment combination in 2012-2013 and 2013-2014 (Table 50).

4.4.4. Carbohydrate content (%)

Irrigation levels had significant effect on carbohydrate content (%) in seed in both the years. The highest carbohydrate content (%) in seed was found in I_1 treatment which was identical with I_2 treatment and the lowest carbohydrate content (%) was obtained from control in both trails (Table 45).

Carbohydrate content (%) in seed differed significantly due to irrigation levels in both trails. Higher carbohydrate content (%) was recorded in S_2 treatment in both the years. The lowest carbohydrate content (%) was observed from S_0 treatment (Table 46).

The effect of boron levels had found to be significant effect on carbohydrate content (%) in both the years. The highest carbohydrate content (%) was found in B_2 treatment which was identical with B_1 and B_3 treatments in both trails. The lowest carbohydrate content (%) was observed from B_0 treatment (Table 47).

The interaction effect of irrigation and sulpher was statistically significant for carbohydrate content (%) in seed in both the years. In 2012-2013 and 2013-2014, the highest carbohydrate content (%) was observed from I_1S_2 treatment combination and the lowest carbohydrate content (%) was found in control treatment combination (Table 48).

Carbohydrate content (%) was not varied significantly due to the interaction of irrigation and boron in both trails (Table 49).

The interaction effect between sulpher and boron levels was statistically significant on carbohydrate content (%) in seed in 2013-2014. In 2013-2014, the highest carbohydrate content (%) was observed from S_2B_2 treatment combination which was statistically similar to $S_2B_1$and S_2B_3 treatment combinations. The lowest carbohydrate content (%) was found in control treatment combination (Table 50).

Table 45. Effect of irrigation on quality of mustard

Irrigation	2012-2013				2013-2014			
	Quality				Quality			
	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)
I_0	6.728b	29.985b	15.213b	24.264b	6.891b	30.125b	15.623b	24.275b
I_1	8.065a	33.648a	18.376a	29.056a	7.872a	33.932a	18.527a	29.051a
I_2	7.681a	32.401a	17.940a	28.733a	7.444a	32.502a	18.166a	28.906a
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS=Not Significant
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

Table 46. Effect of sulpher on quality of mustard

Sulpher	2012-2013				2013-2014			
	Quality				Quality			
	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)
S_0	6.088b	28.789c	11.553b	26.372c	6.249c	29.157b	11.877b	26.504c
S_1	7.435a	31.959b	18.443a	26.876c	7.521b	32.190a	18.856a	26.930c
S_2	8.591a	33.990a	19.680a	28.896a	8.620a	34.025a	19.909a	28.874a
S_3	7.851a	33.308ab	19.030a	27.261b	7.619b	33.374a	19.114a	27.334b
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS=Not Significant
LS=Level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 47. Effect of boron on quality of mustard

Boron	2012-2013				2013-2014			
	Quality				Quality			
	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil Content (%)	Protein content (%)	Carbohydrate content (%)
B_0	6.419b	29.518b	13.373b	24.281b	6.490b	29.916b	13.756b	24.301b
B_1	7.693a	32.708a	18.334a	28.202a	7.805a	32.838a	18.588a	28.295a
B_2	8.021a	33.061a	18.577a	28.577a	8.107a	33.127a	18.800a	28.633a
B_3	7.831a	32.759a	18.422a	28.345a	7.607a	32.863a	18.611a	28.413a
LS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

B_0 = 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2 = 1.5 kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 48. Interaction effect of irrigation and sulpher on quality of mustard

Interaction (I×S)	2012-2013 Quality				2013-2014 Quality			
	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)
I_0 S_0	5.646c	26.133	9.945	21.975ede	5.826f	26.152e	10.249	21.974h
I_0 S_1	7.086cde	30.527	16.446	24.011cde	7.249d	30.567cd	16.889	23.905g
I_0 S_2	7.169cde	31.578	17.491	24.622bcd	7.298d	31.816bc	17.938	26.463fg
I_0 S_3	7.011cde	31.703	16.970	26.450ab	7.191d	31.965bc	17.417	24.756ef
I_1 S_0	6.371de	31.695	12.695	27.555abcd	6.562e	32.655abc	13.031	27.769cde
I_1 S_1	7.702bcd	32.993	19.595	29.403ab	7.769cd	33.356abc	19.895	28.337bcd
I_1 S_2	9.683a	35.588	21.078	30.835a	9.614a	35.493a	21.144	30.767a
I_1 S_3	8.504abc	34.317	20.137	29.605ab	7.543cd	34.226ab	20.038	28.751bcd
I_2 S_0	6.248de	28.538	12.020	27.026bcd	6.359ef	28.664de	12.350	27.269de
I_2 S_1	7.518bcd	32.357	19.287	28.080abc	7.546cd	32.647abc	19.785	29.391abc
I_2 S_2	8.921ab	34.803	20.472	30.188a	8.948b	34.767ab	20.644	30.064ab
I_2 S_3	8.037bc	33.905	19.983	28.463ab	8.125c	33.931ab	19.886	29.478abc
LS	0.01	NS	NS	0.01	0.01	0.01	NS	0.01

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

Table 49. Interaction effect of irrigation and boron on quality mustard

Interaction (I×B)	2012-2013				2013-2014			
	Quality				Quality			
	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)
$I_0 B_0$	5.942e	26.887	10.470e	21.254	6.124f	26.974f	10.778d	21.031
$I_0 B_1$	6.893d	30.730	16.708cd	25.008	7.016de	30.831de	17.151b	25.142
$I_0 B_2$	7.094cd	31.370	16.879bcd	25.572	7.277de	31.533bcde	17.323b	25.614
$I_0 B_3$	6.983cd	30.955	16.795bcd	25.223	7.148de	3cde1.162	17.417b	25.312
$I_1 B_0$	6.654de	32.258	14.966d	25.725	6.682ef	33.2abcd14	13.390c	26.031
$I_1 B_1$	8.339ab	33.720	19.358a	30.081	8.451ab	33.754ab	19.512a	29.684
$I_1 B_2$	8.775a	34.479	19.723a	30.298	8.779a	34.517a	19.789a	30.043
$I_1 B_3$	8.492ab	34.135	19.458a	30.118	7.576cd	34.244a	19.416a	29.866
$I_2 B_0$	6.662de	29.408	14.683d	25.863	6.664ef	29.562e	15.100c	25.840
$I_2 B_1$	7.847bc	33.675	18.937abc	29.515	7.949bc	33.930ab	19.102a	30.060
$I_2 B_2$	8.195ab	33.333	19.128ab	29.862	8.267ab	33.333abc	19.288a	30.242
$I_2 B_3$	8.019ab	33.187	19.014abc	29.693	8.098bc	33.184abc	19.176a	30.060
LS	0.05	NS	0.01	NS	0.01	0.01	0.01	NS

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

I_0 = Control
I_1 = One irrigation
I_2 = Two irrigations

B_0 = 0 kg B ha^{-1}
B_1 = 1 kg B ha^{-1}
B_2 = 1.5kg B ha^{-1}
B_3 = 2 kg B ha^{-1}

Table 50. Interaction effect of sulpher and boron on quality of mustard

Interaction (S×B)	2012-2013				2013-2014			
	Quality				Quality			
	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)
S_0 B_0	5.156i	29.211d	9.226d	23.888	5.275f	24.341g	9.502g	23.976e
S_0 B_1	6.167hi	28.424d	12.192c	27.581	6.371e	28.539cdef	12.531f	27.568c
S_0 B_2	6.636fgh	28.862d	12.470c	28.268	6.795e	28.975bcd	12.809f	28.341bc
S_0 B_3	6.394ghi	28.658d	12.326c	27.766	6.555e	28.772cde	12.664f	27.834bc
S_1 B_0	6.700fgh	29.449d	14.237bc	23.229	6.721e	29.588abc	14.652e	23.028f
S_1 B_1	7.620c-g	32.589c	19.781a	27.312	7.683d	32.905a	20.282bc	27.474c
S_1 B_2	7.741b-g	33.113bc	19.904a	27.539	7.872cd	33.319a	20.403bc	27.820bc
S_1 B_3	7.679b-g	32.684c	19.848a	27.410	7.809cd	32.947a	20.088c	27.693bc
S_2 B_0	6.961d-h	29.822d	15.248b	25.688	7.025e	30.020def	15.671d	25.817d
S_2 B_1	8.934abc	35.182a	20.998a	29.779	9.022ab	35.195ab	21.201ab	29.816a
S_2 B_2	9.407a	35.688a	21.408a	30.141	9.345a	35.607abc	21.493a	29.941a
S_2 B_3	9.062ab	35.267a	21.067a	29.977	9.088ab	35.278abc	21.270ab	29.921a
S_3 B_0	6.861e-h	29.589d	14.781b	24.319	6.940e	29.717h	15.199de	24.383e
S_3 B_1	8.050a-f	34.637ab	20.364a	28.134	8.146cd	34.714fg	20.339bc	28.198bc
S_3 B_2	8.302a-d	34.580ab	20.526a	28.361	8.417bc	34.610efg	20.495abc	28.450b
S_3 B_3	8.190a-e	34.427ab	20.449a	28.228	6.975e	34.456efg	20.421bc	28.307bc
LS	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.05

In a column, figure with same letter (s) or without letter (s) do not differ significantly where as dissimilar letter differ significantly (as per DMRT) at level probability.

NS= not significant.
LS=Level of significant

S_0 = 0 kg S ha^{-1}
S_1 = 30 kg S ha^{-1}
S_2 = 40 kg S ha^{-1}
S_3 = 50 kg S ha^{-1}

B_0 = 0 kg B_0 ha^{-1}
B_1 = 1 kg B_1 ha^{-1}
B_2 = 1.5 kg B_2 ha^{-1}
B_3 = 2 kg B_3 ha^{-1}

Chapter 5

DISCUSIONS

This chapter revealed with the discussion of results of the experiments with the relation to phenological characters, crop growth, yield and yield components and quality of mustard as influenced by irrigation, sulpher and boron levels and their interaction.

All the phenological parameters increased with the advancement of plant growth stages. Increasing moisture availability might be due to increased nutrient absorption which contributed for more number of green leaves and size of leaves, number of branches and plant height. At 40, 60 and 80 DAS, one and two irrigation levels showed statistically similar result on number of leaves with some exception in both the years. Sulpher had significant effect on number of leaves in both the years. S_2 treatment produced the highest number of leaves in both the years at 40, 60 and 80 DAS. With some few exceptions, boron levels had showed significant effect on number of leaves. At 40, 60 and 80 DAS in both the years, B_2 treatment gave the highest number of leaves. With some exceptions, I_1S_2, I_1B_2 and S_2B_2 treatment combinations produced the highest number of leaves in both the years.

Plant height was low at early stages of growth but it increase linearly with increasing irrigation frequencies. Plant height is developed on the number of internodes and their length. The highest plant height was found in two irrigation levels at 20, 40, 60, 80 and 100 DAS in both the years. Sulpher generally tends to increase plant height. Plant height was significantly influenced by sulpher in both the years. S_2 treatment produced the highest plant height in both the years at 40, 60, 80 DAS. The highest plant height was recorded in S_3 treatment at 100 DAS in both the years. Similar results were also reported by Rana *et al*. (2001), Khanpara *et al*. (1993), Sharma (1994) and Chauhan *et al.* (1996).Boron levels plays a vital role in the physiological processes of plant such as cell maturation, cell elongation and cell division carbohydrate, protein, nucleic acid metabolism, cytokinin synthesis and phenol metabolism. With some few exceptions, boron levels had showed significant effect on plant height. With some exceptions, I_1S_2, I_1B_2 and S_2B_2 treatment combinations produced the highest plant height in both the years. This result agrees well with those of Chowdhury *et al*. (1991), Raut *et al.* (2003) and Singh and Meena (2004) of mustard. It enhances cell division, elongation and expiration. Boron levels had significant effect on plant height in both years. The plant height was recorded in B_2 treatment in 2012-2013 and 2013-2014. Similar result was supported by Maih *et al.* (2005) and Thapa (2006).

The total amount of plant dry matter (TDM) production and the pattern of its accumulation were substantially affected by irrigation levels compared to no irrigation. A variation of total dry matter was slow at the early stages of plant growth and widen at later growth stages in both the years. The total dry matter increased with the advantacement of plant age. TDM increased with the irrigation levels. But water stress decreased the cell division, elongation and enlargement that might have ultimately led to reduction in total dry matter. The highest TDM was found in one irrigation with a few exceptions. Significantly the highest TDM was found in S_2 treatment than other treatments in both the years. The highest TDM was found in B_2 treatment with some few exceptions in both the years. Similar result was reported by Dutta *et al.* (1984). Boron is a micronutrient requiring for plant growth relatively to a smalar amount.

The cultivars were not well grown under boron moderate deficiency and toxic boron application. With some exceptions, significantly influenced the highest TDM was observed in the treatment combination of I_2S_2 and I_1B_2 than other treatment combination in both the years. The interaction between sulpher and boron levels had significant effect on TDM in both the years. The highest TDM was observed in S_2B_2 treatment combination. The result obtained from the study is in agreement with those obtained by Karthikeyan *et al*. (2008).

Crop growth rate (CGR) increased slowly at the early stages of plant growth and reached the peak at 40-60 DAS and thereafter it declined. This was possibly due to maximum production of dry matter at initial stages of growth. In present study, irrigation levels had significant and maintained it for a long period. The increase in CGR was presumably due to more availability of nutrients to plants through improved uptake and translocation with irrigation levels. The highest CGR was found in one irrigation with some exceptions in both the years. Similar result was reported by abdul Majid and G.M. Simpson (2002). CGR was significantly influenced by different levels of sulpher in both the years. CGR increased with increasing levels of sulpher upto 40 kg S ha^{-1} and above 50 kg S ha^{-1} decreased the CGR of mustard. The highest CGR was obtained in S_2 treatment with a few exceptions in both the years. Boron levels had significant effect on crop growth rate (CGR) at all data collection period of growth cycle in both the years. With a few exceptions, the highest CGR was found in B_2 treatment in both the years. The similar result was reported by Dutta *et al.* (1984). With a few exceptions, significantly the highest CGR was found in I_2S_2, I_1B_2 and S_2B_2 treatment combination in both the years.

The increase in LAI was due to low leaf osmotic potential that was linked with soil moisture, available to the crop for a long time during the crop growth. The osmotic potential of field grown mustard reported to changes in soil moisture. In present investigation starting from lower value, LAI increased with increase of plant age but decreased at later stages of plant growth. With a few exceptions, the LAI value was higher in I_1 treatment over the control in both the years. The increase in LAI with an increase in the level of irrigation application has also been reported by Bharati *et al.* (2003). This result was supported by Abdul Majid and G. M. Simpson (2002). With a few exceptions, sulpher levels had significant effect on LAI in both the years. Significantly the highest LAI was found in S_2 treatment than other treatments. Resembles that nitrogen increase in LAI can be explained in view of the fact that sulphur resembles that nitrogen in its capacity to enhance cell division and call elongation or expansion. It is reported to have favorable effect on chlorophyll synthesis resulting in more number of leaves with bigger size and higher chlorophyll content .the significant increases in leaf area index in mustard were also recorded by Patel and Shelke (1998). The highest LAI was observed in B_2 treatment with a few exceptions in both the years. This might be due to the effect of boron levels contributed to the increased number of leaves per unit area resulting in increased leaf area. This result is in agreement with the findings of Dutta *et al.* (1984). With a few exceptions, significantly influenced the highest LAI was observed in the treatment combination of I_1S_2, I_1B_2 and S_2B_2 than other treatment combination in both the years.

The increase in net assimilation rate in *B. juncea* is possible due to translocation of stored carbohydrates from roots to tops and pod photosynthesis and an increase in photosynthetic activity. With a few exceptions, the highest NAR was found in I_2 treatment with a few exceptions in both the years. Similar result was reported by Sharma and Kumar (1989) and Abdul Majid and G.M. Simpson (2002). Application of 45 kg S ha^{-1}, significantly enhanced NAR over no sulphur. NAR increased significantly with increasing level of sulphur up to highest dose during both the years of study. The increasing level of sulphur might have increased the number of leaves and leaf area index per plant, which resulted in increased photosynthesis and assimilation rates, cell devotion and cell elongation or expansion. These, in turn, increased the growth characters and NAR. With a few exceptions, S_3 treatment showed the highest NAR in 2012-2013 and 2013-2014. Similar results in mustard were also reported by Yadav (1999) and Saha and Mandal (2000). With a few exceptions, significantly B_2 treatment showed the highest NAR in both the years. Similar result was supported by Dutta *et al.* (1984), Sharma and Kumar (1989). NAR was significantly influenced due to the interaction of irrigation and sulpher levels during 20-40 and 60-80 DAS in 2012-2013 and 40-60 DAS and 60-80 DAS in 2013-2014. During 20-40 DAS in 2012-2013, the highest NAR was obtained from the treatment combination of I_1S_2. At 40-60 DAS in 2012-2013, the highest NAR was found in I_2S_2 combination and in 2013-2014, the highest value was obtained in I_1S_3 treatment combination. During 60-80 DAS in 2013-2014, I_2S_1 treatment combination gave the highest NAR. NAR had significantly influenced due to interaction of irrigation and boron levels within the period of 20-40 and 40-60 DAS in 2012-2013. During 20-40 DAS (2012-2013), the highest NAR was found in the treatment combination of I_1B_2. Within the period of 40-60 DAS in 2012-2013, the highest NAR was observed from the treatment combination of I_2B_1. The interaction between sulpher and boron levels had significantly influenced on NAR during the period of 20-40 DAS in both the years. During the period of 20-40 DAS in 2012-2013, the highest NAR was obtained from S_2B_2 treatment combination and in 2013-2014, the highest NAR was obtained from S_3B_2 treatment combination.

Irrigation increases the availability of water and nutrient through the establishment of relatively favourable moisture conditions around root zone of crop. Water stress may affect every stage of plant growth and physiology, especially the reproductive phase. One irrigation produced the highest number of branches in both the years. Similar type of results has also been reported by Yusuf (1973), Singh and Srivastava (1986) and Jadhav (1988). Jaoder *et al.* (1979) and Clark and Simpson (1978) found that irrigation scarcely affected by number of branches. Result shows that number of branches had significant effect on the sulpher levels in both the years. In both the years, the highest number of branches was found in S_2 treatment. Similar result was reported by Singh (1984), Malekuzzaman (2002) and Raut *et al.* (2003). Boron levels had significant effect on number of branches in both the years. The maximum number of branches was given by B_2 treatment. The result is in conformity with the findings of Maih *et al.* (2005). The interaction between sulpher and boron levels had significant effect on number of branches in both the years. The highest number of branches was found in S_2B_2 treatment combination in both the years.

It is observed that the highest number of siliqua plant^{-1} was produced by I_2 treatment which was not statistically significant in 2012-2013 and in 2013-2014, number of siliqua plant^{-1} was significantly influenced by irrigation. The highest number of siliqua plant^{-1} was obtained in I_1 treatment. This might be due to more availability of soil moisture. The result is in conformity with the findings of Clark and Simpson (1978), Sharma and Kumer (1989). Significantly the highest number of siliqua plant^{-1} was observed in S_3 treatment in 2012-2013 and in 2013-2014, S_2 treatment gave the highest number of siliqua plant^{-1}. Similar result was reported by Chatterjee *et al.* (1985), Raut *et al.* (2003) and Yeasmin *et al.* (2013). Number of siliqua plant^{-1} was affected significantly due to boron levels in both the years. B_2 treatment gave the highest number of siliqua plant^{-1} in both trails. The result is in conformity with the findings of Maih *et al.* (2005), Thapa (2006) and Yeasmin *et al.* (2013). The interaction of irrigation and sulpher did not show significant effect on number of siliqua plant^{-1} in 2012-2013. Significantly the highest number of siliqua plant^{-1} was recorded from I_2S_2 treatment combination. Number of siliqua plant^{-1} had differed significantly due to the interaction effect of irrigation and boron levels in both the years. The highest number of siliqua plant^{-1} was obtained from I_1B_2 treatment combination in 2012-2013 and in 2013-2014, the highest number of siliqua plant^{-1} was found from I_1B_2 treatment combination. The interaction between sulpher and boron levels was found to be significant in respect of number of siliqua plant^{-1} in both the years. The highest number of siliqua plant^{-1} was found in S_2B_2 treatment combination in both trails. Similar result was reported by Haque (2000) and Yeasmin *et al.* (2013).

Levels of irrigation had significantly influenced on the siliqua length in both the years. The highest length of siliqua was obtained from one irrigation at flowering stage in both the years. This might be due to the steady availability of moisture during growth period of mustard. The result was supported by Hossain *et al.* (2013). Siliqua length was significantly influenced due to sulpher levels in both the years. S_2

treatment gave the highest siliqua length in 2012-2013 and 2013-2014. In 2012-2013 and 2013-2014, different levels of boron had significantly influenced on the siliqua length. The highest siliqua length was recorded from B_2 treatment in both the years. The interaction of irrigation and sulpher levels showed significant effect on siliqua length in 2012-2013 and 2013-2014. The highest siliqua length was recorded from I_1S_2 treatment combination in both trails. Siliqua length had differed significantly due to the interaction effect of irrigation and boron levels in both the years. The highest siliqua length was obtained from I_1B_2 treatment combination in 2012-2013 and 2013-2014. Significantly the highest siliqua length was observed from S_2B_2 treatment combination in 2012-2013 and 2013-2014.

The number of seeds siliqua^{-1} had differed significantly due to the irrigation levels in both the years. The highest number of seeds siliqua^{-1} was produced by one irrigation. The result is in conformity with the findings of Sarkar and Hassan (1988), Sharma and Kumar (1989), Prasad *et al.* (1988) and Hossain *et al.* (2013). The S fertilizer at 40 kg ha^{-1} produced the highest number of seeds siliqua^{-1}. Increase number of seeds siliqua^{-1} in mustard was reported by Chowdhury *et al*. (1991), Das and Das (1995) and Rana and Rana (2003). Similar results were also reported by Singh *et al.* (2002) and Yadav *et al.* (2014). Different levels of boron had significantly influenced on the number of seeds siliqua^{-1} in 2012-2013 and 2013-2014. The higher number of seeds siliqua^{-1} was obtained from 1.5 kg B ha^{-1} in both trails. Similar result was reported by Maih *et al.* (2005) and Yeasmin *et al.* (2013). The interaction of irrigation and sulpher levels showed significant effect on number of seeds siliqua^{-1} in 2012-2013 and 2013-2014. The highest number of seeds siliqua^{-1} was recorded from I_1S_2 treatment combination. Irrigation and boron levels had significant interaction effect on number of seeds siliqua^{-1} in both the trails. The highest number of seeds siliqua^{-1} was found in I_1B_2 treatment combination. The interaction between sulpher and boron levels was found to be significant effect in respect of number of seeds siliqua^{-1} in both the years. The highest number of siliqua plant^{-1} was found in S_2B_2 treatment combination in both trails. The result obtained from the study is in agreement with those obtained by Chatterjee *et al.* (1985).

Significantly the highest number of normal seeds siliqua^{-1} was observed from one irrigation in 2012-2013 and 2013-2014. The number of normal seeds siliqua^{-1} was significantly influenced by the sulphur application in both trails. The highest number of normal seeds siliqua^{-1} was produced in S_2 treatment in both the years. Similar result was supported by Yeasmin *et al.* (2013). It has been observed that significantly the highest number of normal seeds siliqua^{-1} was produced by B_2 treatment in 2012-2013 and 2013-2014. Similar result was supported by Yeasmin *et al.* (2013). The interaction between irrigation and sulpher levels showed significant effect on number of normal seeds siliqua^{-1} in 2012-2013 and 2013-2014. The highest number of normal seeds siliqua^{-1} was recorded from I_1S_2 combination treatment. The number of normal seeds siliqua^{-1} had differed significantly due to the interaction effect of irrigation and boron levels in both years. The highest number of normal seeds siliqua^{-1} was obtained from I_1B_2 treatment combination in 2012-2013 and 2013-2014. The interaction between sulpher and boron levels was found to be significant in respect of number of normal seeds siliqua^{-1} in both the years. The highest number of number of normal seeds siliqua^{-1} was found in S_2B_2 treatment combination in both trails.

Two irrigation produced the lowest number of deformed seeds siliqua^{-1} and the highest number of deformed seeds siliqua^{-1} from control irrigation in both the years. The application of 40 kg S ha^{-1} produced the lowest number of deformed seeds siliqua^{-1} and the highest number of deformed seeds siliqua^{-1} was produced from control treatment in both trails. The number of deformed seeds siliqua^{-1} was significantly influenced by different levels boron in both the years. The lowest number of deformed seeds siliqua^{-1} was recorded when 1.5kg B ha^{-1} was applied, on the other hand the highest number of deformed seeds siliqua^{-1} was recorded in control.

It can be seen that irrigation levels had significant effect on 1000-seed weight in 2012-2013 and 2013-2014. One irrigation levels produced the highest 1000-seed weight in both the years. The result was obtained in the study were supported by Sarkar and Hassan (1988) and Sharma and kumar (1989) who reported that increasing frequency of irrigation increased 1000-seed weight. Similar result was also supported by Prasad *et al.* (1988) and Hossain *et al*. (2013). Sulphur levels had significant effect on 1000-seed weight in both the years. The highest 1000-seed weight was produced by S_2 treatment in 2012-2013 and 2013-2014. Similar result was reported by Chowdhury *et al*. (1991), Das and Das (1995) Malekuzzam (2002) and Yeasmin *et al*. (2013). The 1000-seed weight was significantly affected by boron levels in both trails. The higher 1000-seed weight was recorded when 1.5 kg B ha^{-1} was applied in 2012-2013 and 2013-2014. Similar result was supported by Maih *et al.* (2005) and Yeasmin *et al.* (2013). Combination effect of irrigation and sulpher levels had significantly influenced on 1000-seed weight in 2012-2013. Maximum 1000-seed weight was recorded when I_1S_2 treatment combination was applied. 1000-seed weight was significantly influenced by the interaction effect of irrigation and boron levels in 2012-2013. The highest 1000-seed weight was found in I_1B_2 treatment combination. Combination effect of sulphur and boron levels had also significantly influenced on 1000-seed weight in both the years. Maximum 1000-seed weight was recorded when S_2B_2 treatment combination was applied in 2012-2013 and 2013-2014. Similar result was supported by Yeasmin *et al.* (2013).

Seed yield is ultimate goal of mustard cultivation. Seed yield is associated with the number of normal seeds siliqua^{-1} and 1000-seed weight. Irrigation increases the number of normal seeds siliqua^{-1} and 1000-seed weight which ultimately led to increase seed yield. This might be due to the fact that reproductive organs are determined much before the emergence of siliqua and largely governed by the vegetative growth and initiation of flower primordia. Better vegetative growth ultimately builds higher yield attributing characters due to increased absorption of mineral nutrients under adequate moisture conditions. Growth characters were highest which contributed for highest yield attributes due to increased photosynthetic activity and translocation of photosynthates from source to sink. Significantly the highest seed yield was produced by one irrigation levels in both the years. The result obtained from the study is in agreement with those obtained by Stoker and Carter (1984), Joarder *et al.* (1979), Sharma and kumar (1989), and Singh and Srivastava (1986). Similar result was also supported by Hossain *et al.* (2013). Sulpher levels showed significant variation in seed yield for both the years. Significantly the highest seed yield was recorded from S_2 treatment in both trails. The improvement of yield components *viz.* the number of seeds siliqua^{-1} due to application of sulphur were response to the enhancement of seed yield. The enhancement of seed yield in mustard due to the application of sulphur has been reported by many researchers *viz.* Singh *et al*. (1970), Sarkar *et al*. (1997), Singh and kumar (1996), Sharma *et al.* (1999) and

Suresh *et al*. (2002). Raut *et al.* (2003) observed that increased dose of sulphur produced highest seed yield. Chatterjee *et al*. (1985) observed that the almost similar result. Similar result was also supported by Singh *et al.* (2000), Kumar *et al.* (2004), Yeasmin *et al*. (2013) and Hossain *et al.* (2013). The application of 1.5 kg B ha^{-1} boron produced the highest seed yield in both the years. Boron is essential for growth of new cells. Without adequate supply of boron, the number and retention of flowers reduces, and pollen tube growth is less; consequently less siliqua are developed, less seed yield appearance. Similar result was supported by Thapa (2006), Maih *et al.* (2005) and Yeasmin *et al.* (2013). Seed yield was significantly influenced by the interaction effect of irrigation and sulpher levels in 2013-2014. The highest seed yield was obtained from the interaction effect of I_1S_2 treatment combination in 2013-2014. The interaction between irrigation and boron levels had significant effect on seed yield in 2013-2014. The maximum seed yield was recorded from the I_1B_2 treatment combination in 2013-2014. The interaction between sulphur and boron levels showed significant effect on seed yield in both the years. The highest seed yield was obtained from the treatment combination of S_2B_2 in 2012-2013 and 2013-2014. Similar result was also supported by Haque (2000), Thapa (2006), Moniruzzaman *et al.* (2008) and Yeasmin *et al.* (2013).

Trend of straw yield due to application of different level of irrigation was very much to seed yield in both the years. The level of two irrigation produced the highest straw yield in both the years. The cause of increase in straw yield might be due to increasing number of branches and plant height of mustard. Similar result was also supported by Hossain *et al.* (2013), Malavia (1988), Prasad (1995) and Sharma (1994). The effect of sulphur on straw yield of mustard was significant in both the years. The rate of 40 kg S ha^{-1} produced the highest straw yield in both the years. Similar result was also supported by Yeasmin *et al*. (2013). Straw yield was significantly influenced by different levels of boron application in both trails. The maximum straw yield was observed when 1.5kg B ha^{-1} was applied as basal dose. Similar result was also supported Yeasmin *et al.* (2013). The irrigation and sulpher interaction had significant effect on straw yield in 2012-2013. The highest straw yield was found in the treatment combination of I_2S_2 in 2012-2013. Straw yield was significantly influenced by the interaction effect of irrigation and boron levels in 2012-2013. The highest straw yield was obtained from I_1B_2 treatment combination in 2012-2013. Sulphur and boron levels had significant effect on straw yield in both the years. The highest straw yield was found from the treatment combination of S_2B_2 in both trails.

One irrigation levels produced significantly the highest biological yield in both the years. Sulphur levels had significant effect on biological yield in both the years. The highest biological yield was produced by S_2 treatment in 2012-2013 and 2013-2014. The higher biological yield was recorded when 1.5 kg B ha^{-1} (B_2) was applied in 2012-2013 and 2013-2014. The highest biological yield was found in I_1S_2 and I_1B_2 treatment combinations in 2012-2013. Combination effect of sulphur and boron levels had also significant effect on biological yield in both the years. Maximum biological yield was recorded when S_2B_2 treatment combination.

Two irrigations produced significantly the highest harvest index in 2012-2013 and 2013-2014. The effect of sulphur on harvest index of mustard was significant in 2012-2013 and 2013-2014. The highest harvest index was found in S_2 treatment in 2012-2013 and 2013-2014. Harvest index was significantly influenced by different levels of boron application in 2012-2013 and 2013-2014. The maximum harvest index was observed in B_2

treatment in 2012-2013 and 2013-2014. The highest harvest index was obtained from I_1B_1 treatment combination in 2013-2014. Sulphur and boron interaction had significant effect on harvest index in 2012-2013.

Irrigation levels had significant effect in moisture content (%) in seed in both the years. The highest moisture content (%) in seed was found in I_1 treatment in both trails. Moisture content (%) in seed differed significantly due to sulpher levels in both trails. Higher moisture content (%) was recorded in S_2 treatment. The effect of boron levels was found to be significant effect in respect of moisture content (%) in both the years. The highest moisture content (%) was found in B_2 treatment. With some exceptions, I_1S_2, I_1B_2 and S_2B_2 treatment combination produced the highest moisture content (%) in both the years.

Significantly the highest oil content (%) was found in one irrigation levels in both the years. Sulpher fertilizer enhances the oil formation in oil crops. Results showed that S_2 treatment produced the highest oil content (%) in both trails. The result obtained from the study is in agreement with those obtained by Singh and Bairathi (1980), Singh *et al.* (1987), Das and Das (1995), Sarkar *et al.* (1998), Ahmed *et al.* (1998), Singh *et al.* (2000) and kumar *et al. (*2004). Boron levels had significant effect on oil content (%) in both trails. The highest oil content (%) was found in B_2 treatment in both the years. Similar result was also supported by Thapa (2006). Results showed that I_1S_2 treatment combination produced the highest oil content (%) in 2013-2014. Oil content (%) varied significantly due to the interaction of irrigation and boron levels in 2013-2014. The highest oil content (%) was observed in I_1B_2 treatment combination in 2013-2014. Significantly highest oil content (%) was recorded in S_2B_2 treatment combination in both trails. The result obtained from the study is in agreement with those obtained by Karthikeyan *et al.* (2008).

The highest protein content (%) was found in one irrigation levels in both the years. Sulpher plays a important role in the increases of quality of protein. The effect of sulpher levels was significant for protein content (%) in both the years. Results showed that S_2 treatment produced the highest protein content (%) in both trails. The result obtained from the study is in agreement with those obtained by Singh and Bairathi (1980). Boron plays a vital role in protein and nucleic acid metabolism, cytokinin synthesis, acid and phenol metabolisms. Boron levels had significant effect on protein content (%) in both trails. The highest protein content (%) was found in B_2 treatment in both the years. The interaction effect of irrigation and boron levels was found to be significant effect in respect of protein content (%) in 2012-2013 and 2013-2014. Results showed that I_1S_2 treatment combination produced the highest protein content (%) in 2012-2013 and 2013-2014.

The highest protein content (%) was observed in S_2B_2 treatment combination in both the years. The result obtained from the study is in agreement with those obtained by Karthikeyan *et al.* (2008).

Irrigation levels had significant effect in carbohydrate content (%) in seed in both the years. The highest carbohydrate content (%) in seed was found in I_1 treatment in both trails. Carbohydrate content (%) in seed differed significantly due to irrigation in both trails. Higher carbohydrate content (%) was recorded in S_2 treatment. The effect of boron was found to be significant effect in respect of carbohydrate content (%) in both the years. The highest carbohydrate content (%) was found in B_2 treatment. Boron deficiency produces pollen grains that are small and that do not accumulate carbohydrate. Pollens that develop normally may still be affected by boron deficiency. The interaction effect of irrigation and sulpher was statistically significant for carbohydrate content (%) in seed in both the years. In 2012-2013 and 2013-2014, the highest carbohydrate content (%) was observed from I_1S_2 treatment combination. The interaction effect between sulpher and boron was statistically significant for carbohydrate content (%) in seed in 2013-2014. In 2013-2014, the highest carbohydrate content (%) was observed from S_2B_2 treatment combination.

CONCLUSIONS

With a few exceptions, at different phonological stages, the highest plant height and number of leaves were observed in one irrigation, S_2 (40kg ha^{-1}) and B_2 (1.5kg ha^{-1}) treatment and the lowest values were found in control

From the experiment it may be concluded that one irrigation at flowering stage, 40kg S ha^{-1} and 1.5 kg B ha^{-1} produced the height total dry matter, crop growth rate, leaf area index and net assimilation rate with a few exceptions.

One irrigation also produced the highest yield components like plant height (cm), number of siliqua^{-1} plant, siliqua length (cm), number of seeds siliqua^{-1}, number of normal seeds siliqua^{-1}, 1000-seed weight (g) and maximum seed yield (t ha^{-1}) and straw yield (t ha^{-1}) were found when the field was irrigated at flowering stage.

40 kg S ha^{-1} and 1.5 kg B ha^{-1} gave the highest yield components. Maximum yield of mustard were obtained when applied sulpher and boron doses are 40kg S ha^{-1} and 1.5kg B ha^{-1} were applied.

Application of one irrigation with at the rate of 40kg S ha^{-1} and 1.5kg B ha^{-1} are better for quality of mustard like moisture content (%), oil content (%), protein content (%) and carbohydrate content (%).

The experiment may be repeated for onfarm trails at different agro-ecological regions of Bangladesh to confirm the findings of the present experiment.

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APPENDICES

Appendix I. Morphological characteristics of soil

Constituent	Characteristics
1. Location	Agronomy Field laboratory western side of the Department of Agronomy and Agriculture Extension, Rajshahi university
2. Land type	Medium High land
3. General soil type	Non calcareous dark grey soil
4. Agro-ecological zone (AEZ)	AEZ-11: High ganges River flood
5.Topography	Fairly level
6. Soil color	Drak grey
7. Drainage	Well drainage
8. Soil series	Gopalpur series

Appendix II. Physical characteristics of the initial soil (0-15 cm depth)

Constituent	Results*
Particle size analysis	
Sand (%) (0.0-0..2mm)	60
Silt (%) (o.02-0.002 mm)	25
Clay (%) 9<0.002 mm)	15
Soil texture class	Sandy loam

*= result obtained from the mechanical analysis of the initial soil sample was done in the soil Resource Development institute, Regional Research Station, shampur, Rajshahi.

Appendix III. Chemical characteristics of initial soil (0- 15 cm depth)

SI. No	Soil characteristics	Analytical data
1	PH	8.4
2	Total Nitrogen (%)	0.04
3	Organic Matter (%)	0.46
4	Available phosphorus (ppm)	11.33
5	Available Sulphur (ppm)	3.10
6	Exchangeable Potassium (ppm)	0.19
7	Zinc (ppm)	0.78

Source : Soil Resource and Development Institute (SRDI), Regional Centre , Rajshahi

Appendix IV. Monthly temperature, relative humidity and rainfall during the study period (October 2012 to March 2013) at Rajshahi University Campus, Rajshahi

Month	Year	**Air temperature (^{0}C)			** Humidity (%)	* Rainfall (mm)
		Maximum	Minimum	Average		
October	2012	30.9	23.5	26.5	87	204
November	2012	29.1	16.3	21.8	77	-
December	2012	25.0	13.1	18.1	81	-
January	2013	22.5	11.5	16.2	83	2.0
February	2013	25.5	13.1	18.6	77	27.0
March	2013	32.1	17.7	24.4	67	12.3

Source: Regional Meteorological Station, Shaympur, Rajshahi

* = Monthly total

** = Monthly average

Appendix V. Monthly temperature, relative humidity and rainfall during the study period (October 2013 to March 2014) at Rajshahi University Campus, Rajshahi

Month	Year	**Air temperature (°C)			**Relative Humidity (%)	*Rainfall (mm)
		Maximum	Minimum	Average		
October	2013	32.1	22.6	26.7	83	51.1
November	2013	29.8	16	21.7	78	-
December	2013	24.2	12.3	17.2	83	-
January	2014	23.3	11.6	16.6	83	13.8
February	2014	28.1	14.7	22.6	78	14.2
March	2014	32.6	17.9	24.7	67	39.8

Source : Regional Meteorological Station, Shaympur, Rajshahi

* = Monthly total

** = Monthly average

Appendix VI. Summary of analysis of variance for plant height on mustard

Sources of variation	Degrees of freedom	(2012-2013) Plant height					(2013-2014) Plant height				
		20DAS	40DAS	60DAS	80DAS	100DAS	20DAS	40DAS	60DAS	80DAS	100DAS
Irrigation (I)	2	0.581NS	1220.071**	2350.153**	4723.490**	2680.070*	0.033NS	1180.920**	2289.087 **	4614.581 **	2451.063*
Error	4	0.795	10.552	66.843	113.550	205.593	0.824	10.591	67.685	105.240	205.832
Sulphur (S)	3	0.092NS	2419.047**	5623.575**	10562.010**	5733.909**	1.415NS	2333.328**	5344.686 **	10192.701**	5215.038 **
I × S	6	0.675NS	152.565**	144.043NS	362.616*	179.400NS	0.389NS	150.475 **	141.641 NS	349.668*	179.685NS
Error	18	0.376	5.621	159.572	97.572	374.855	0.685	5.615	162.148	103.481	375.495
Boron (B)	3	0.494NS	1196.855**	2930.860**	4777.958**	3259.194**	2.310NS	1150.496**	2760.304 **	4535.113 **	2947.556 **
I × B	6	1.979NS	131.558 **	321.322*	390.455 **	306.182NS	0.356NS	131.109 **	229.086*	390.834**	300.316NS
S × B	9	1.251NS	153.891 **	188.971NS	477.090 **	213.525NS	1.619NS	151.276 **	181.506 NS	482.290**	207.905NS
Error	72	0.346	7.716	94.776	51.952	279.770	0.377	7.716	94.608	52.421	280.209
Total	143										

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix VII. Summary of analysis of variance for number of leaves on mustard

Sources of variation	Degrees of freedom	(2012-2013)				(2013-2014)			
		Number of leaves				Number of leaves			
		20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
Irrigation (I)	2	0.031NS	28.003**	254.171**	83.110**	0.039NS	22.302**	236.211**	73.011**
Error	4	0.829	1.021	1.503	1.435	0.806	1.063	1.508	1.480
Sulphur (S)	3	1.421NS	49.299**	509.593**	328.331**	1.399NS	37.492**	469.756**	296.647**
I × S	6	0.390NS	0.764NS	4.876NS	4.639*	0.393NS	0.788NS	4.652NS	4.866*
Error	18	0.685	1.254	2.228	1.614	0.684	1.250	2.268	1.629
Boron (B)	3	2.307NS	21.168**	280.013**	141.420**	2.335NS	15.407**	257.823**	125.821**
I × B	6	0.354NS	0.239NS	8.109**	1.341*	0.358NS	0.257NS	7.953**	1.350*
S × B	9	1.620NS	1.176NS	10.516**	9.699**	1.608N	0.987NS	10.102**	10.127**
Error	72	0.376	0.865	0.999	0.596	0.381	0.870	1.003	0.586
Total	143								

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix VIII. Summary of analysis of variance for total dry matter (TDM) on mustard

Sources of variation	Degrees of freedom	Mean square value							
		(2012-2013)				(2013-2014)			
		Total dry matter(TDM)				Total dry matter (TDM)			
		20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
Irrigation (I)	2	0.000NS	0.281**	15.689**	21.063**	0.001NS	0.330**	11.443**	47.965**
Error	4	0.000	0.002	0.008	0.129	0.002	0.001	0.099	0.066
Sulphur (S)	3	0.000NS	1.050**	36.392**	103.564**	0.002NS	0.813**	54.775**	111.906**
I × S	6	0.000NS	0.008*	0.376**	0.730**	0.000NS	0.015**	0.565*	1.570**
Error	18	0.000	0.003	0.060	0.124	0.000	0.002	0.159	0.243
Boron (B)	3	0.000NS	0.701**	22.717**	68.339**	0.000NS	0.461**	40.067**	78.610**
I × B	6	0.000NS	0.003*	0.191**	0.311**	0.001NS	0.007**	0.076NS	0.714*
S × B	9	0.000NS	0.007**	0.588**	0.955**	0.001NS	0.019**	0.279**	2.327**
Error	72	0.000	0.001	0.048	0.055	0.000	0.002	0.082	0.236
Total	143								

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix IX. Summary of analysis of variance for crop growth rate (CGR) on mustard

Sources of variation	Degrees of freedom	Mean square value					
		(2012-2013)			(2013-2014)		
		Crop growth rate(CGR)			Crop growth rate(CGR)		
		20-40 DAS	40-60 DAS	60-80 DAS	20-40 DAS	40-60 DAS	60-80 DAS
Irrigation (I)	2	4.870**	307.075**	11.245NS	7.666**	198.611**	313.955**
Error	4	0.072	0.234	2.220	0.052	2.683	0.638
Sulphur (S)	3	25.944**	629.799**	446.414**	18.874**	1057.511**	263.208**
I × S	6	0.255*	7.548**	2.495*	0.398**	11.320NS	10.152*
Error	18	0.082	1.339	0.877	0.034	4.274	3.398
Boron (B)	3	16.859**	386.051**	307.992**	11.743**	799.239**	162.979**
I × B	6	0.081*	4.139**	2.062NS	0.119*	1.849NS	11.258NS
S × B	9	0.172**	12.427**	4.619**	0.416**	4.832*	29.107**
Error	72	0.029	1,140	1.351	0.046	2.116	5.115
Total	143						

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix X. Summary of analysis of variance for leaf area index (LAI) on mustard

Sources of variation	Degrees of freedom	Mean square value							
		(2012-2013)				(2013-2014)			
		Leaf area index(LAI)				Leaf area index(LAI)			
		20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS	80DAS
Irrigation (I)	2	0.003NS	0.360**	1.840**	1.614**	0.000NS	0.356**	0.410**	1.331**
Error	4	0.007	0.000	0.037	0.023	0.000	0.001	0.014	0.040
Sulphur (S)	3	0.005NS	0.840**	5.299**	7.519**	0.000NS	0.793**	3.036**	6.953**
I × S	6	0.009NS	0.010**	0.035*	0.063*	0.000NS	0.009**	0.026**	0.042*
Error	18	0.027	0.001	0.011	0.019	0.000	0.001	0.010	0.011
Boron (B)	3	0.005NS	0.502**	2.664**	8.160**	0.000NS	0.485**	2.542**	7.815**
I × B	6	0.010NS	0.004**	0.051**	0.078**	0.000NS	0.004**	0.011NS	0.018NS
S × B	9	0.014NS	0.016**	0.055**	0.112**	0.000NS	0.014**	0.067**	0.069**
Error	72	0.108	0.000	0.015	0.015	0.000	0.001	0.009	0.008
Total	143								

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix XI. Summary of analysis of variance for net assimilation rate (NAR) on mustard

Sources of variation	Degrees of freedom	Mean square value					
		(2012-2013)			(2013-2014)		
		Net assimilation rate(NAR)			Net assimilation rate(NAR)		
		20-40 DAS	40-60 DAS	60-80 DAS	20-40 DAS	40-60 DAS	60-80 DAS
Irrigation (I)	2	0.319	1.185NS	33.520**	0.059NS	27.351**	2.794NS
Error	4	0.009	0.553	0.929	0.076	0.176	1.875
Sulphur (S)	3	1.076**	2.088NS	14.024**	1.129**	13.880**	18.841**
I × S	6	0.029**	5.607**	1.493NS	0.045NS	0.806*	1.750*
Error	18	0.007	1.013	1.091	0.070	0.284	0.612
Boron (B)	3	0.669**	14.969**	1.281NS	0.775**	2.089**	1.724**
I × B	6	0.036*	1.702*	0.779NS	0.034NS	0.463NS	0.321NS
S × B	9	0.028*	1.038NS	1.733NS	0.115*	0.494NS	0.577NS
Error	72	0.013	0.682	0.895	0.049	0.343	0.370
Total	143						

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix XII .Summary of analysis of variance for the yield and yield attributes on mustard (2012-2013)

Sources of variation	Degrees of freedom	Mean square value										
		No. of branches plant^{-1}	No. of siliqua plant^{-1}	Siliqua length	No. of seeds siliqua^{-1}	No. of Normal seeds Siliqua^{-1}	No. of deformed seed sliliqua^{-1}	1000 seeds weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	biological yield (t ha^{-1})	Harvest index (%)
Irrigation (I)	2	347.832*	4723.491**	3.482**	14.210NS	21.551**	1.736**	3.055**	0.970**	5.667**	12.035**	64.680**
Error	4	24.890	113.550	0.021	0.249	0.175	0.021	0.010	0.024	0.004	0.012	1.948
Sulphur (S)	3	689.929 **	10562.010 **	24.083**	119.502**	153.018**	2.624**	12.731**	4.149**	12.625**	32.443*	27.572*
I × S	6	6.205NS	362.616*	0.152*	5.178**	4.497**	0.215NS	0.214**	0.042NS	0.126**	0.341**	1.169NS
Error	18	6.998	97.572	0.040	0.714	0.462	0.298	0.029	0.018	0.020	0.031	5.836
Boron (B)	3	385.205**	4777.958**	21.099**	110.559**	134.877**	1.227**	10.409**	3.328**	8.443**	22.926**	9.341NS
I × B	6	0.091NS	390.455**	0.086**	1.143*	0.991*	0.049NS	0.194**	0.004NS	0.085**	0.094**	4.678NS
S × B	9	2.269*	477.090**	0.769**	2.438**	2.386**	0.090NS	0.435**	0.110**	0.303**	0.762**	7.866*
Error	72	1.013	51.952	0.024	0.453	0.393	0.061	0.021	0.014	0.022	0.029	3.728
Total	143											

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix XIII. Summary of analysis of variance for the yield and yield attributes on mustard (2013-2014)

Sources of variation	Degrees of freedom	Mean square value									
		No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds siliqua^{-1}	No. of Normal seeds Siliqua^{-1}	No. of deformed seed sliliqua^{-1}	1000 seeds weight (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	biological yield (t ha^{-1})	Harvest index (%)
Irrigation (I)	2	327.146*	4407.044**	9.667**	16.539**	1.958**	21.872**	1.961**	1.452**	7.070**	112.688**
Error	4	24.982	112.900	0.277	0.191	0.031	0.038	0.001	0.070	0.090	1.654
Sulphur (S)	3	643.583**	9846.665**	99.454**	131.692**	2.778**	52.629**	4.368**	12.215**	24.560**	19.412NS
I × S	6	6.261NS	355.991*	4.794**	4.244**	0.209NS	0.621**	0.044**	0.155**	0.298**	6.225**
Error	18	6.956	98.281	0.675	0.462	0.258	0.057	0.007	0.069	0.141	14.165
Boron (B)	3	359.305**	4385.295**	95.743**	119.668**	1.364**	30.389**	2.922**	8.891**	3.991NS	368.918NS
I × B	6	0.109NS	381.635**	1.085*	0.977*	0.054NS	0.235**	0.030**	0.043NS	0.091NS	11.344**
S × B	9	2.277*	456.713**	2.125**	2.104**	0.071NS	0.979**	0.105**	0.421**	0.971*	71.634NS
Error	72	1.006	51.993	0.445	0.388	0.061	0.052	0.008	0.038	0.422	35.003
Total	143										

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant

Appendix XIV. Summary of analysis of variance for quality on mustard

Sources of variation	Degrees of freedom	Mean square value							
		(2012-2013)				(2013-2014)			
		Quality				Quality			
		Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Oil content (%)	Protein content (%)	Carbohydrate content (%)
Irrigation (I)	2	22.747**	166.451**	141.075**	354.239**	13.653**	177.517**	120.250**	344.263**
Error	4	0.580	1.612	3.456	1.996	0.045	0.428	0.735	8.147
Sulphur (S)	3	39.733**	191.794**	515.109**	38.409**	34.008**	167.648**	502.22**	42.951**
I × S	6	2.401**	8.155**	0.745NS	20.905**	2.874**	13.454**	0.519NS	23.203**
Error	18	0.300	5.047	3.483	0.449	0.050	1.207	0.732	1.767
Boron (B)	3	19.033**	100.365**	231.851**	155.423**	17.924**	83.060**	217.318**	151.692**
I × B	6	0.563*	5.704NS	3.588**	0.271NS	1.211**	11.093**	5.461**	0.364NS
S × B	9	0.652**	17.207**	3.946**	0.424*	1.497**	22.755**	3.167**	0.146NS
Error	72	0.236	3.034	0.695	0.182	0.060	0.751	0.135	1.027
Total	143								

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Non significant