GROWTH AND YIELD OF RAPESEED (*Brassica campestris*) AS AFFECTED BY SULPHUR AND BORON FERTILIZER

A THESIS

BY

SULTANA RAZIA

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

SULTANA RAZIA
Registration No.: 08-03037

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Approved by:

(Prof. Dr. Md. Hazrat Ali)	**(Prof. Dr. Md. Abdullahil Baque)**
Supervisor	Co-Supervisor

(Prof. Dr. Md. Fazlul Karim)
Chairman
Examination Committee

Dr. Md. Hazrat Ali
Professor
Department of Agronomy
Sher-e-Bagla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207
Bangladesh
E-mail: hazratali11@yahoo.com
Cell No.: +88-01714396906

CERTIFICATE

This is to certify that the thesis entitled ***"GROWTH AND YIELD OF RAPESEED (Brassica campestris) AS AFFECTED BY SULPHUR AND BORON FERTILIZER"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***SULTANA RAZIA, Registration. No. 08-03037*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: 29/02/2016
Dhaka, Bangladesh

(Prof. Dr. Md. Hazrat Ali)
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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GROWTH AND YIELD OF RAPESEED (*Brassica campestris*) AS AFFECTED BY SULPHUR AND BORON FERTILIZER

ABSTRACT

An experiment was done at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from Robi, 2013-14 to investigate the growth and yield performance of rapeseed as affected by sulphur (S) and boron (B). The experiment was laid out in two factors randomized complete block design (RCBD) with three replications. There were 16 treatment combinations (4 S doses x 4 B doses). The sulphur treatments were 0 kg ha^{-1} (S_0), 18.6 kg ha^{-1} (S_1), 27.9 kg ha^{-1} (S_2) and 37.2 kg ha^{-1} (S_3). Boron treatments were 0 kg ha^{-1} (B_0), 0.875 kg ha^{-1} (B_1), 1.75 kg ha^{-1} (B_2) and 2.625 kg ha^{-1} (B_3). Results showed that highest plant height (113.18 cm) was achieved at the combination of 37.2 kg ha^{-1} S dose and 1.75 kg ha^{-1} B dose. The highest dry matter (16. 8 g) was produced at the combination of 37.2 kg ha^{-1} S and 2.625 kg ha^{-1} B. The highest siliquae plant^{-1} (209.67), siliqua length (5.33) and seeds siliqua^{-1} (25.2) was achieved at the combination of 37.2 kg ha^{-1} S and 2.625 kg ha^{-1} B, 27.9 kg ha^{-1} S and 2.625 kg ha^{-1} B, 18.6 kg ha^{-1} S and 0 kg ha^{-1} B, 27.9 kg ha^{-1} S and 0 kg ha^{-1} B, 27.9 kg ha^{-1} S and 2.625 kg ha^{-1} B respectively. The lowest sterility percentage (3.03%) was observed at the combination of 37.2 kg ha^{-1} S and 1.75 kg ha^{-1} B. The highest grain yield (3.07 t ha^{-1}) and harvest index (36.07%) was obtained at the combination of 27.9 kg ha^{-1} S dose and 1.75 kg ha^{-1} B dose and 0 kg ha^{-1} S dose and 0 kg ha^{-1} B dose. Highest weight of 1000-seed (3.83 g) was found at the combination of 27.9 kg ha^{-1} S and 0.875 kg ha^{-1} B. The highest oil percentage (41.32) was obtained at the combination of 37.2 kg ha^{-1} S and 1.75 kg ha^{-1} B.

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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BARI	Bangladesh Agricultural Research Research Institute
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAS	Days After Sowing
et al.	And others
e.g.	*exempli gratia* (L), for example
etc.	Etcetera
FAO	Food and Agricultural Organization
g	Gram (s)
HI	Harvest Index
i.e.	*id est* (L), that is
IRRI	International Rice Research Institute
kg	Kilogram (s)
kg ha^{-1}	kg per hectare
LSD	Least Significant Difference
m^2	Meter squares
MS	Master of Science
No.	Number
NS	Non significant
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resource and Development Institute
var.	Variety
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme
°C	Degree Centigrade
%	Percentage

Chapter 1

Introduction

INTRODUCTION

Rapeseed is one of the important oil seed crops of the world after soybean and palm (FAO, 1996). About 13.2% of the annual edible oil comes from rapeseed and mustard (FAO, 2005). *Brassica* oil crop is the most important group that supplies major edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country (AIS, 2010). Bangladesh is running a short of 60-75% of the demand of edible oil (Rahman, 2002). In Bangladesh these crops cover less than 3% of the total cultivated land. Total area and annual production of mustard and rapeseed crops are 2.42 lac hectare and 2.22 lac metric tons respectively (BBS, 2010). The average grain yield of mustard is only 0.92 t ha^{-1} (BBS, 2010), which is very low as compared to that of advanced countries in the world. The poor yield of mustard might be attributed to different genetical as well as environmental conditions. It is possible to increase the yield per unit area by adopting improved cultural practices, of which the use of high yielding varieties coupled with an application of balanced fertilizers is very important.

In view of population growth, the requirement of edible oil is increasing day by day. It is therefore, expected that the production of edible oil should be increased considerably to fulfill the demand through increased seed yield.

Sulphur is considered as one of the major nutrient elements (platou and johns, 1982), required for plant growth as in the same order as that of phosphorus (Zhao *et al.*, 1997). Mustard is highly susceptible to S-shortage and responds well to S-fertilization (McGrath and Zhao, 1996; Haque, 2000). On the other hand, an excessive S-supply can lower the quality of mustard meal, used by animal, by increasing the glucosinolate concentration.

The importance of sulphur is increasing in crop production. The major reserve of this element in oil in the organic fraction. Crops grown on soils that have 1.2-1.5%

organic matter often require S-fertilization. Further, the response of crops to added-S may be related with species as well as with varieties.

Sulphur is an important element, for the cultivation of mustard, which plays a vital role to increase the yield by improving yield components including the oil content (Dubey and Khan, 1991). Sulphur also influence the uptake of nitrogen, phosphorus and potassium (Singh *et al.*, 1988). In general, about 97 percent soils of Bangladesh are deficient in sulphur and this deficiency is becoming acute, day by day, mainly due to intensive crop production coupled with the use of sulphur free fertilizers (Mazid, 1986). Hence, it is desirable to know how sulphur affects the yield attributes of mustard. Ahmad *et al.* (1998) carried out an experiment with *Brassica* species where 0, 40 and 60 kg S ha^{-1} and 60, 100 and 150 kg N ha^{-1} were used. They reported that application of S and N increased yield components, seed and oil yield with the highest yield given by 40 kg S and 100 kg N ha^{-1}, respectively.

Besides the drought resistant, yield in some crops has been reported to increase with the application of boron (B) and phosphorus. In fertilizer schedule, an inclusion of B some time decides the success and failure of the crops (Dwivedi *et al.*, 1990). It is reported that the ranges between the deficiency and toxicity of B are quite narrow and that an application of B can be extremely toxic to plants at concentrations only slightly above the optimum rate. Gupta *et al.* (1994) emphasizes the need for a judicial use of B fertilizer. Information to that end is practically meager in our country.

In addition N, P and K, deficiencies of some micronutrients such as Zn, B and Mo have appeared in some soils and crops of Bangladesh (Jahiruddin *et al.*, 1995; Islam *et al.*, 1997 and 1999; Khanam *et al.*, 2001).

Crops require trace amount of boron for their growth and development. Crops differ in their sensitivity to boron deficiency. Brassica crops, in general, have a high boron requirement (Mengel and Kirkby, 1987) and they are sensitive to low B-supply and severe deficiency may result in floral abortion and significant drop in seed production (Yang *et al.*, 1989). Chatterjee *et al.* (1985) reported that gypsum application at the rate of 20 kg S ha^{-1} in conjugation with borax (10 kg B ha^{-1}) caused 42% increase in seed yield of rapeseed. *Brassica napus* often shows sterility in many areas of the country. It is suspected that this variety is highly sensitive to boron deficiency (Zaman *et al.*, 1998).

The above discussion suggests that in order to improve productivity of rapeseed, the limiting nutrients need to be identified.

Keeping the above points in view, the present piece of work was undertaken to

I. study the effect of sulphur on the growth & yield of rapeseed.
II. study the effect of boron on the growth & yield of rapeseed.
III. find out the interaction effects of sulphur and boron on the growth and yield of rapeseed.

Chapter 2
Review of literature

REVIEW OF LITERATURE

Investigation on the influence of S and B application on the growth and yield of rapeseed have been progressed in many countries of the world. The available literature related to this study is reviewed here.

2.1 Effect of Sulphur (S) on rapeseed

Sulphur has been recognized for over 100 years as one of the essential elements required for the growth of plants. Global reports of sulphur deficiency and consequent crop responses are quite ostensible (Singh and Rathi, 1984).

Sulphur is required by crops in about the same amounts as phosphorus and is therefore recognized by many agriculturists as the fourth important nutrient (BARC, 1986). Sulphur plays an important role in the synthesis of protein and the essential sulphur containing amino acids, methionine and cysteine, vitamins and chlorophyll. It is essential for the activation of certain enzymes and is a vital constituent of ferrodoxin which participate in the photosynthesis process. As sulphur is involved in photosynthesis, deficiency decreases chlorophyll content and young leaves turn yellow showing interveinal chlorosis. Growth is stunted and the flowers have smaller petals which are pale yellow.

Sulphur has vital influence on growth and yield of mustard. When deficiency symptoms of sulphur noticeable rapeseed becomes severely lacking in sulphur. Pods form slowly, are small and poorly filled with shriveled seeds.

2.1.1 Plant height

BARI (1985) reported that the plant height of mustard increased significantly due to the application of S.

Singh and Saran (1987) reported that application of 30 kg S ha^{-1} increased plant height, consequently produced significant seed yiled of mustard.

Kanpara *et al.* (1992) observed that the growth character of mustard such as plant height was significantly increased up to 100 kg S ha^{-1}.

Singh and Saran (1993) reported that sulphur @30 kg ha^{-1} significantly the plant height, leaf area index, siliqua $plant^{-1}$, dry matter and finally seed yield compared with the control. There was no significant difference in respect of these parameters between 30 and 60 kg S ha^{-1}. No significant differential effect of sulphur was noticed on primary branches, siliqua length and 1000-seed weight.

2.1.2 Number of primary branches $plant^{-1}$

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

Saran and Giri (1990) observed that primary branches $plant^{-1}$ were increased significantly with 60 kg S ha^{-1}.

Kanpara *et al.* (1992) observed that the growth character of mustard such as primary and secondary branches $plant^{-1}$ was significantly increased up to 100 kg S ha^{-1}.

Chauhan *et al.* (1996) observed that each successive increase in S level from 0-50 kg ha^{-1} significantly increased the number of branches $plant^{-1}$.

2.1.3 Dry matter production

Direct and residual effects of sulphur and magnesium were studied by Nad and Goswami (1983), in a three-crop sequence of legumes and oil seed on three alluvial soils in India. Cowpea and mustard responded to direct application of sulphur by increasing both dry matter an S uptake irrespective of the sulphur status of the soils.

2.1.4 Number of siliquae $plant^{-1}$

Samui *et al.* (1983) reported that when $ZnSO_4$ was applied it increased the number of siliquae $plant^{-1}$ of rapeseed.

Saran and Giri (1990) observed that siliqua plant^{-1} were increased significantly with 60 kg S ha^{-1}.

Chauhan *et al.* (1996) observed that each successive increase in S level from 0-50 kg ha^{-1} significantly increased the number of siliqua plant^{-1}.

Tomar *et al.* (1997) observed that sulphur had significant effect on of siliquae plant^{-1}, seeds siliqua^{-1} and seed yields of mustard up to 80 kg S ha^{-1}.

2.1.5 Number of seeds siliqua^{-1}

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

BARI (1982) reported that the application of S was favourable for the production of more seeds siliqua^{-1} in comparison to plants not fertilized with S.

Samui *et al.* (1983) reported that when $ZnSO_4$ was applied it increased the number of seeds siliqua^{-1} of mustard.

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

Saran and Giri (1990) observed that seeds siliqua^{-1} were increased significantly with 60 kg S ha^{-1}.

Sulphur is a macronutrient occurring in soil both in organic and inotganic forms. Organic form provides the major source of S in soils. The principal S bearing mineral is gypsum ($CaSO_4.2H_2O$). Plants absorb S in the form of SO_4^{2-}. Sulphur carries out many functions for growth and development of plants. Sulphur is involved in the synthesis of amino acids (cysteine, cystine and methionine), coenzyme A, biotin, thiamine (Vit. B_1) and chlorophyll. It is vital part of ferrodoxins. It helps in the synthesis of oil and formation of seeds (Tisdale *et al.*, 1997).

Das and Das (1995) observed that sulphur application had no significant eefect on growth and yield attributes except seeds siliqua^{-1} and 1000-seed weight.

Chauhan *et al.* (1996) observed that each successive increase in S level from 0-50 kg ha^{-1} significantly increased the number of seeds siliqua^{-1}.

Tomar *et al.* (1997) observed that sulphur had that sulphur had significant effect on of seeds siliqua^{-1} of mustard up to 80 kg S ha^{-1}.

2.1.6 1000-seed weight

Samui *et al.* (1983) reported that when $ZnSO_4$ was applied it 1000-seed weight of mustard.

Saran and Giri (1990) observed that 1000-seed weight were increased significantly with 60 kg S ha^{-1}.

Das and Das (1995) observed that sulphur application had no significant eefect on growth and yield attributes except seeds siliqua^{-1} and 1000-seed weight.

2.1.7 Grain and stover yield

Jaggi and Sharma (1997) reported that application of S progressively increased the seed and straw yileds. However, the effect was significant up to 60 kg S ha^{-1} in seed and 90 kg S ha^{-1} in straw yield.

Auklah *et al.* (1979) in their study on rapeseed observed that with the use of S alone or in combination with potash increased vegetative growth and seed yield significantly. Sulphur and potash showed synergistic effect, increased dose increased the seed yield.

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

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

Wetter *et al.* (1970) observed that mustard required large amount of S for high seed yield.

Studder (1971) concluded that winter rape produced the maximum seed yield when fertilized with 200 kg N together with 50 kg of S ha^{-1}.

Singh and Singh (1984) in contrast found that there was no effect of S on yield attributes of toria probably due to the amount of S present in the soil was addequat to sustain the optimum plant growth and development.

Application of 75 kg S ha^{-1} in the form of SSP (single super phosphate) proved to be best treatment for increasing and improving the quality of the soybean yield (Sharma *et al.*, 2001).

Miah *et al.* (2001) conducted an experiment with high yielding varieties of mustard (Binasarisha-1, Binasarisha-3, Shonalisarisha and BARI Sarisha-6). Five dose 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, up to 45 kg ha^{-1}. Similar results were also reported by Babhulkar *et al.* (2000).

Singh *et al.* (2000) conducted fertilizer trial experiment using S @ 0, 15, 45 and 60 kg ha^{-1}. They reported that grain yield, total S-uptake, oil yield increased with successive increase in S-application up to 45 kg ha^{-1} in comparison to that of the control. Mean increase of grain yield and oil content due to S was 159 kg ha^{-1} and 3.7%, respectively.

Ahmad *et al.* (1998) carried out an experiment with *Brassica* species where 0, 40 or 60 kg S ha^{-1} and 60, 100 or 150 kg N ha^{-1} were used. They reported that application of S and N increased yield components, seed and oil yield with the highest yield given by 40 kg S and 100 kg N ha^{-1}, respectively.

Zhao *et al.* (1997) conducted 29 field trials in UK to see the effect of S on yield of rapeseed. They observed that there was a need to maintain a balanced N and S supply for both yield and quality.

Tomar *et al.* (1997) showed that yield of *Brassica juncea* cv Krishna was increased with up to the highest fertilizer rates of 80 kg S ha^{-1}.

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

Ali *et al.* (1988) from their experiments, using different combinations of N, P, K and Zn fertilizers, found sharp response to fertilizer application. Yield increase due to application of S was the most striking. At 40 kg S ha^{-1}, seed yield mustard was 300% more than that was obtained in S control plots. Increase in yield due to S-rates of 20 kg and 60 kg ha^{-1} were 226% and 317%, respectively.

Singh *et al.* (1987) observed that application of 30 kg S ha^{-1} to *Brassica campestris* gave yields of 1.16 t ha^{-1} compared to 1.00 t ha^{-1} without S. Yield was not further increased with higher rates up to 60 kg S ha^{-1}.

Rahman *et al*. (1984) observed significant increase of mustard seed yield in trials conducted on the Darsona series of calcareous brown flood plain soils of Jessore with the increasing application of sulphur upto 20 kg S ha^{-1}.

Narwal *et al*. (1991) conducted pot experiment in a greenhouse with *Brassica juncea* CV. RH-30 was given 0, 30, 60, 90 or 120 μg S soil as superphosphate, gypsum, pressmud (filter cake) or pyrites. Grain and stem yields, total S uptake and oil yield increased with increasing S application rate. The highest seed and oil yields and S uptake were obtained with 120 μg S g^{-1} S as gypsum and the lowest with pyrites.

Sulphur starved rape produced very low quality of oil (Rahman, 1977). In fact rapeseed and mustard required large amounts of sulphur to give a high seed yields.

Sarker *et al*. (1992) carried out an experiment at the Bangladesh Agricultural University Mymensingh with four high yielding varieties of mustard BAU-M/12 (Sampad), BAU-M/248 (Sambol), M-257 and SS-75 (Sonali Sarisha) to investigate their response to five levels of sulphur viz. 0, 10, 20, 30 and 40 kg S ha-1. The seed yield was maximum in BAU-M/248 (Sambol) when-fertilized with sulphur at the rate of 40 kg S ha-1 in comparison to other varieties and rate of sulphur. The variety 'Sampad' followed 'Sambol' in respect of seed yield at this level of sulphur fertilizer. The seed yield of M/257 and SS-75 (Sonali Sarisha) were found to be maximum at 30 kg S ha^{-1}.

2.1.8 Oil content

Aulakh (1980) reported that an application of 60 kg S ha^{-1} increased the oil content y 12 percent in yellow mustard (*B. campestrs*) and 16 percent in mustard (*B. juncea*).

Yaduvanshi *et al.* (1980) observed that an application of 200 kg S ha^{-1} with NPK provided the highest oil content from 34.7% in control to 43.7% in S treatment.

Singh and Bairathi (1980) reported that the seed yields, the N, P and S uptake, and the oil and protein contents in seeds of *Brassica juncea* were increased with 75-150 kg S and/or 40 kg N ha^{-1}. They also reported that application of 30 kg P_2O_5 ha^{-1} increased the yield, N and P uptake in both years and S uptake in 1 year, but had no effect on oil and protein contents.

Sulphur is involved in the synthesis of amino acids (cysteine, cystine and methionine), coenzyme A, biotin, thiamine (Vit. B_1) and chlorophyll. It is vital part of ferrodoxins. It helps in the synthesis of oil and formation of seeds (Tisdale *et al.*, 1997).

2.2 Effects of boron (B) on rapeseed

Boron has both direct and indirect effects on fertilizer. Indirect effects are related to increase in amount and change in sugar composition of the nectar, whereby the flowers of species that rely on pollinating insects become more attractive to insects (Erikson, 1979). Direct effects of boron are reflected by the close relationship between boron supply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.*, 1981). Moreover, boron stimulates pollen germination, particularly pollen tube growth. Boron is also essential for sugar translocation, thus affecting carbon and nitrogen metabolism of plants (Jackson and Champman, 1975). Thus it affects the seed formation and development and consequently the yield of crops.

Crops require trace amount of boron for their growth and development. Crops differ in their sensitivity to boron deficiency. Brassica crops, in general, have a high boron requirement (Mengel and Kirkby, 1987) and they are sensitive to low B-supply and severe deficiency may result in floral abortion and significant drop in seed production (Yang *et al.*, 1989).

Mustard plant belongs to the genus Brassica under the family Cruciferae. The Brassica has three species. They are *B. napus*, *B. campestris* and *B. junecea* which are grown in different regions of our country. Of these *B. napus* and *B. campestris* are the greatest importance in the world's oil seed trade. Recently Binasarish-4 and Binasarisha-5, the varieties of high yield potential with water logging and salinity tolerance and alternaria resistance, have been developed by the scientists of BINA. *Brassica napus*, the mother of these new developed genotypes, often shows sterility in many areas of the country. It is suspected that this variety is highly sensitive to boron deficiency (Zaman *et al.*, 1998).

Liu *et al.* (2000) conducted experiment on the effect of boron and molybdenum stress on NR activity and contents of nitrate-N in leaves of three soybean cultivars. The results showed that NR activity was reduced and contents of nitrate-N were increased by boron and molybdenum toxicity.

In field and pot trials of rapeseed with B, N and K, Yang *et al.* (1989) reported that B application increased B content in all plant parts, but especially in leaves. Seed yield was positively correlated with soil and especially leaf B content. Application of B, N and K promoted growth, CO_2 assimilation and NR activity in leaves.

While working with mustard (*Brassica campestris* L. var. Sarson) Khurana *et al.* (2002) grew plants in refined sand, at three levels of B, deficient (0.3 μM), normal (30 μM), and excess (300 μM) boron, along with low (0.02 mM) and normal (2 mM) sulphur. Dry matter and reproductive yield were the highest at combined supply of adequate boron and sulphur. Foliar symptoms of boron deficiency were accentuated by low sulphur. Boron (B) deficiency at normal sulphur reduced chlorophyll content, hill reaction, and the activities of peroxidase, acid phosphatase and ribonuclease. At excess boron, resulted decrease in biomass and pod yield, chlorophyll and P concentrations were pronounced at low sulphur levels. Similar influence of boron on the parameters cited above were reported by Sharma and Ramchandra (1990).

Hemantaranjan *et al.* (2000) conducted an experiment with foliar application of boron as boric of 50 and 100 ppm and soil application of individual and combined rates of sulphur at 40 and 80 mg kg^{-1} soil and iron at 15 and 29 mg kg^{-1} soil. The plant height, root length, total dry matter production and seed yield of soybean were higher at 50 than at 100 ppm B. However, chlorophyll a content was higher at 100 ppm.

Application of 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 (Dutta *et al*., 1984)

Tamak *et al.* (1997) observed in a field trial on sunflower cv. MSFH8 using 0, 30, 60 or 90 kg P_2O_5 ha^{-1} or 50 kg S ha^{-1} along with 0.28 ppm boron sprayed or not sprayed. Seed yield increased significantly with up to 60 kg P_2O_5 and 25 kg S along with folair application of boron. Oil content of seeds was increased by all fertilizers, while protein content was increased by S but decreased by P and B.

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

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

Sinha *et al.* (2000) grew mustard (*Brassica campestris* L) in sand with three levels of boron (B): deficient (0.0033 ppm), normal (0.33 ppm) and excess (3.3 ppm), along with three levels of zinc (Zn): low (0.00065 ppm), adequate (0.065 ppm) and high (6.5 ppm). The boron deficiency effects were accentuated by low zinc, in the accumulation of reducing sugars and stimulated activities of peroxidase. Excess boron accelerated the effects of high Zn by reducing the biomass and economic yield.

Ramchandra *et al.* (1987) from a trial work, where *Brassica campestris*, [*Brassica napus* var. glauca] plants were grown under B deficiency (0.0033 and 0.0066 ppm B) conditions, showed retarded apical growth, deformation of the young leaves and death of apical meristems leading to a bushy appearance. B deficiency decreased ribonucleic acid and protein contents and increased sugar, starch and phenol contents.

2.3 Interaction effect of sulphur and boron

Crops require a certain amount of sulphur and boron for their growth and development. Crops differ in their sensitivity to sulpur and boron deficiency.

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

Chapter 3

Materials and Methods

MATERIALS AND METHODS

3.1 Site selection

The research work was carried out at experimental field of Agronomy Department of Sher-e- Bangla Agricultural University, Dhaka during the period from November 2004 to February 2005. The field was located at southeast part of main academic building. The soil of the experimental plot belongs to the Agro ecological zone of the Modhupur Tract (AEZ-28). The details of materials and methods employed during the course of this investigation are presented hereunder.

3.2 Soil

Soil samples from 0-15 cm depths were collected from experimental field. The collected soil sample was mainly sandy to silty and loamy in texture. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physio-chemical properties of the soil are presented in Appendix I.

3.3 Climate

The experimental area is under the subtropical climate. Usually the rainfall was heavy during Kharif season and scanty in Rabi season. The atmospheric temperature increased as the proceeds towards Kharif season. The weather conditions of crop growth period such as monthly rainfall (mm), mean temperature (^{O}c), sunshine hours/day and humidity (%) are presented in Appendix II.

3.4 Planting material

The variety used for the present study was BARI Sarisha-15. The seeds of these variety were collected from the Oilseed Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found over 90% for all the varieties.

3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubbles and weeds were removed. The first ploughing and the final land preparation were done on October 27 and November 3, 2013, respectively. Whole experimental land was divided into unit plots following the design of experiment. The plots are spaded one day before planting and the basal dose of fertilizers for better incorporation of fertilizers and soil.

3.6 Fertilizer application

The land was fertilized uniformly with following fertilizer dose. Sulphur and Boron fertilizers were applied to the plot as per treatment in the form of gypsum (18% S) and Boric Powder. One third of the urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining urea was top dressed int two splits at 17 and 27 days after sowing (DAS). Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc oxide and boric acid were used as source of nitrogen, phosphorus, potassium, sulphur, zinc and boron respectively. The rate of N, P_2O_5, K_2O and Zn was 115-82-51-7.8 kg ha^{-1} respectively (BARI, 2002).

3.7 Experimental Materials and Treatment Combinations

3.7.1 Experimental Materials

The experiment was two factorials with four sulphur doses and four boron doses.

A. Silphur Fertilizer Dose:

S_0= 0 kg ha^{-1}

S_1= 18.6 kg S ha^{-1} or 100 kg ha^{-1} gypsum

S_2= 27.9 kg S ha^{-1} or 150 kg ha^{-1} gypsum

S_3= 37.2 kg S ha^{-1} or 200 kg ha^{-1} gypsum

B. Boron Fertilizer Dose:

B_0= 0 kg ha^{-1}

B_1= 0.875 kg B ha^{-1} or 5 kg ha^{-1} boric acid

B_2= 1.75 kg B ha^{-1} or 10 kg ha^{-1} boric acid

B_3= 2.625 kg B ha^{-1} or 15 kg ha^{-1} boric acid

3.7.2 Treatment Combinations

Treatments	Combination of S & B doses
T_1	S_0B_0
T_2	S_0B_1
T_3	S_0B_2
T_4	S_0B_3
T_5	S_1B_0
T_6	S_1B_1
T_7	S_1B_2
T_8	S_1B_3
T_9	S_2B_0
T_{10}	S_2B_1
T_{11}	S_2B_2
T_{12}	S_2B_3
T_{13}	S_3B_0
T_{14}	S_3B_1
T_{15}	S_3B_2
T_{16}	S_3B_3

3.7.3 Experimental Design and Layout

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. There were 16 treatments (4 Sulphur doses x 4 Boron doses). The size of unit plot was 3 m x 3 m. The distance between two rows was 30 cm and plant to plant 5 cm. The drainage channels were made 15 cm below from the adjacent soil with soil surface.

3.8 Germination test

Germination test was performed before sowing the seeds in the field. Petridishes were used for laboratory test. Three layers of filter paper were placed on petridishes and the filter papers were soft with water. Seeds were distributed at random in four petridishes. Each petridish contained 25 seeds. Data on emergence were collected on percentage basis by using the following formula:

$$Germination\ (\%) = \frac{Number\ of\ seed\ germinated}{Number\ of\ seeds\ taken\ for\ germination} \times 100$$

3.9 Sowing of seeds in the field

The seeds were sown in rows made by hand rake on November 4, 2013. The seeds were placed continuously within the rows at a depth of 2-3 cm from the soil surface.

3.10 Intercultural operations

3.10.1 Thinning

Thinning operation was done on November 15, 2013 (15 days after sowing) and November 25, 2013 (25 days after sowing) with maintaining population density.

3.10.2 Irrigation and weeding

Two irrigations were given during the life cycle. The first irrigation was given at 20 DAS (days after sowing) on November 24, 2013 and the second was done at 40 DAS on 14 December, 2013. The crop field was weeded twice, first weeding was done at 16 DAS on November 20, 2013 and second weeding was done at 26 DAS on November 30, 2013. Demarcation boundaries and drainage channels were also kept weed free.

3.10.3 Plant protection

At middle stage of growth, Aphids attacked the crop. To control this pest, Sumithion 50 EC@ 20 ml/10 liter water was sprayed twice on December 20, 2013 (45 DAS) and January 5, 2014 (61 DAS).

3.11 Sampling and data collection

The first sampling was done at 30 DAS and it was continued at an interval of fifteen days, viz. 45 DAS, 60 DAS and 75 DAS. Three plants were selected and marked at each plot. The height of plants was measured with a scale placed on the ground level to top of the leaves. Number of branches, number of siliquae, siliqua length, number of seeds/siliqua, weight of 1000 seeds, sterility percentage were recorded separately. Each time 3 plants were selected from each plot for measuring dry matter weight. Selected plants of each plot were uprooted carefully by a khurpi and washed in running tape water to remove the soil. Then the plants were dried under sun for one day. Then these were transferred into electric oven. After 15 days the dries plants were weighed on an electric balance.

3.12 Harvest and post-harvest operations

Harvesting was done on January 28, 2014 (85 DAS). The harvest area (1 m^2) was maintained by leaving the border rows from which the grain weight, straw weight and 1000 seed weight were collected after proper drying. The harvest index was later calculated from the data.

3.13 Recording of data

The data on crop characters were recorded at harvest. The yield and yield contributing characters were recorded from the selected plants and from harvest area in each plot.

3.14 Procedure of recording data

3.14.1 Plant height (cm)

The height of pre-selected plants from each plot were measured with a meter scale from the ground level to the top of the plants at 30, 45, 60, 75 DAS and at harvest and the mean height was expressed in cm.

3.14.2 Number of branches plant^{-1}

The primary and secondary number of branches was collected from each sample plant and the mean data was recorded.

3.14.3 Number of leaves plant^{-1}

Number of leaves were calculated from each sample plant and the mean data was recorded. W_2-W_1

3.14.4 Crop growth rate (g plant^{-1} day^{-1})

Crop growth rate was calculated by using the following standard formula (Radford, 1967 and Hunt, 1978) as shown below:

CGR= $(W_2-W_1) \div (T_2-T_1)$ g plant^{-1} day^{-1}

Where, W_1= Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

3.14.5 Relative growth rate (g plant^{-1} day^{-1})

Relative growth rate was calculated by using the following formula (Radford, 1967) as shown below:

RGR= $(LnW_2-LnW_1) \div (T_2-T_1)$ g plant^{-1} day^{-1}

Where, W_1 = Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

Ln = Natural logarithm

3.14.6 Number of siliquae plant^{-1}

Number of total siliquae of ten plants from each unit plot was noted and the mean number was expressed as per plant basis.

3.14.7 Length of siliqua

The length of 10 siliquae from each samples were collected randomly and the mean number was expressed as per siliqua basis (cm).

3.14.8 Number of seeds siliqua^{-1}

Number of total seeds of ten randomly sampled siliquae from each plot was noted and the mean number was expressed as per siliqua basis.

3.14.9 Weight of 1000 seeds (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance and the mean weight were expressed in gram.

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

Dry weight of seed from harvested area of each plot was taken and then converted to ton per hectare.

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

Dry weight of straw from harvested area of each plot was taken and then converted to ton per hectare.

3.14.12 Shell yield (t ha^{-1})

Dry weight of siliqua shell from harvested area of each plot was taken and then converted to ton hectare^{-1}.

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

Biological yield was calculated by summing up the total seed yield, straw yield and sliqua shell yield.

3.14.14 Harvest index

The harvest index was calculated on the ratio of grain yield to biological yield and expressed into percentage. It was calculated by using the following formula:

$$Harvest\ Index\ (\%) = \frac{Grain\ Yield}{Biological\ Yield} \times 100$$

3.14.15 Oil content of seed

The oil content of seeds was determined by "Soxhlet" method in percentage. This was done in Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701.

Estimation of oils/fats

Reagents & Equipments

1. Anhydrous ethyl ether 2. Soxhlet, flask and condenser 3. Hot plate

Procedure

Dried mustard flour sample was weighed out into an extraction thimble. Weight of thimble and sample were recorded in laboratory book. The thimble was placed into the soxhlet. 50-100 ml ethyl ether was added to the soxhtet flask then it was connected to holder and condenser. Soxhlet flask was placed on hot plate and distilled at low temperature for 16-20 hours. After extraction it was turned off and allowed to cool. When distillation was ceased, the extraction thimble was removed and allowed to air dry for 30-40 minutes the thimble was weighed out. The loss of weight was cured fat.

3.15 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the CROPSTAT (Version 7.2, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by 5% level of significance (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the growth and yield of rapeseed as affected by sulphur and boron fertilizers. To strength in discussion, information in the form of table and figures are added. The whole chapter has been has been categorized and presented under the following headings.

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of sulphur doses

The plant height (cm) of rapeseed was significantly influenced by different sulphur doses throughout the growing period (Appendix V and Figure 1). At 30 DAS rapeseed plant scored the highest plant height (30.08 cm) at 37.2 kg ha^{-1} sulphur. The lowest plant height (20.64 cm) was observed at 0 kg ha^{-1} sulphur. Every treatment was statistically significant from others. On 45 DAS highest plant height (101.28 cm) was recorded at 37.2 kg ha^{-1} sulphur and the lowest plant height (92.39 cm) was observed at 0 kg ha^{-1} sulphur which was statistically similar (94.97 cm) with 18.6 kg ha^{-1} sulphur dose. In case of 60 DAS, highest plant height (111.56 cm) was recorded at 37.2 kg ha^{-1} sulphur and the lowest plant height (104.76 cm) was observed at control or 0 kg ha^{-1} sulphur which was statistically similar (107 cm) with 18.6 kg ha^{-1} sulphur. At 75 DAS and at harvest the highest plant height (111.27 and 111.26 cm) was recorded at 37.2 kg ha^{-1} sulphur dose and the lowest plant height (104.72 and 104.63 cm) was observed at control or 0 kg ha^{-1} sulphur which was statistically similar (106.98 and 106.85 cm) with 18.6 kg ha^{-1} sulphur. BARI (1985) and Kanpara *et al.* (1992) reported that the plant height of mustard increased significantly due to the application of S.

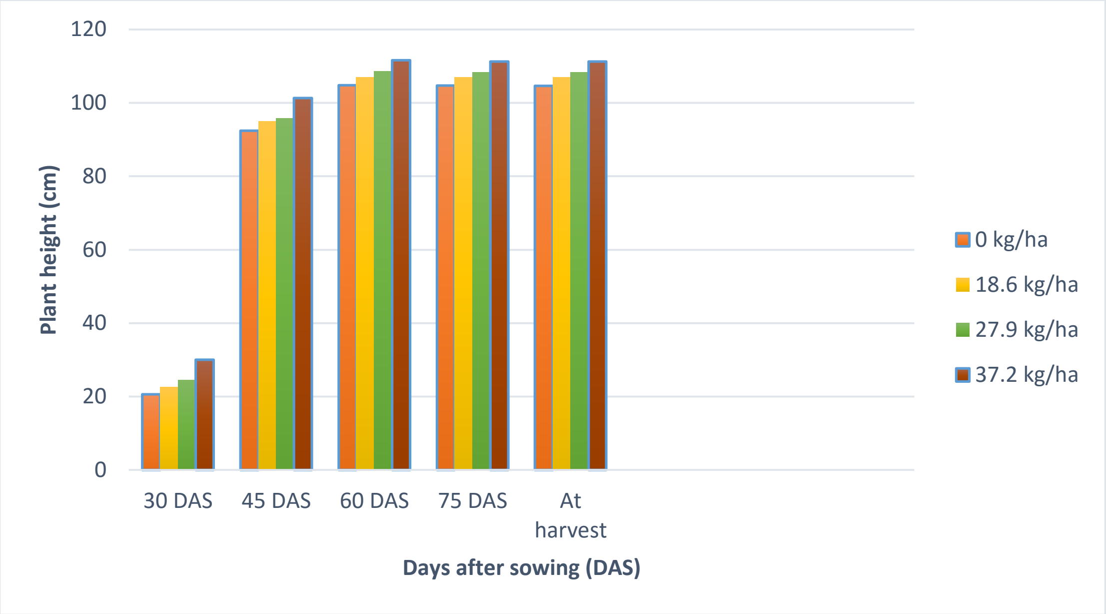

Figure 1. Effect of sulphur doses on plant height of rapeseed at different DAS ($LSD_{0.05}$= 1.58, 3.04, 2.63, 2.6 and 2.6 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.1.2 Effect of boron doses

The plant height (cm) of rapeseed was not significantly varied by different boron doses throughout the growing period (Appendix V and Figure 2). At 30 DAS, rapeseed plant scored the highest plant height (25.1 cm) at 0 kg ha^{-1} boron which was statistically similar with 0.875 kgha^{-1} (24.76 cm) and 1.75 kg ha^{-1} (24.52 cm) boron doses. The lowest plant height (23.35 cm) was recorded at 2.625 kg ha^{-1} boron which was statistically similar with 0.875 kgha^{-1} (24.76 cm) and 1.75 kg ha^{-1} (24.52 cm) boron doses. On 45 DAS, all of the treatments showed statistically similar result. But the highest plant height (97.03 cm) was recorded at 1.75 kg ha^{-1} boron dose and the lowest plant height (94.7 cm) was recorded at 2.625 kg ha^{-1} boron. In case of 60 DAS, 75 DAS and at harvest all of the treatments also showed statistically similar result. But, the highest plant height (108.76, 108.63 and 108.56 cm) was recorded at 1.75 kg ha^{-1} boron and the lowest plant height (107.16, 106.89 and 106.88 cm) was observed at 0.875 kg ha^{-1} boron dose.

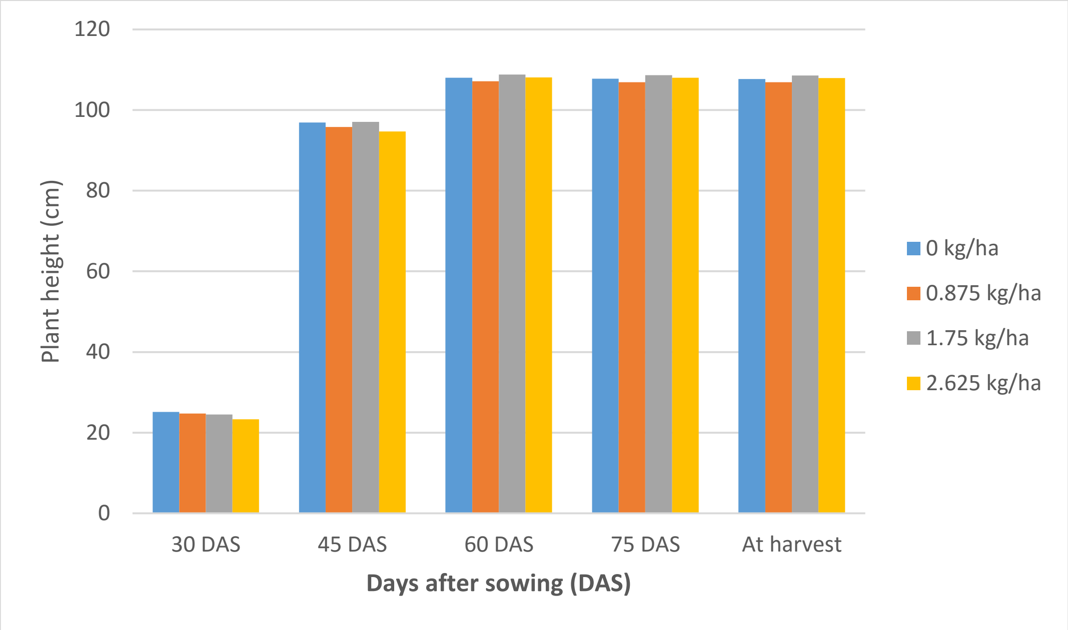

Figure 2. Effect of boron doses on plant height of rapeseed at different DAS ($LSD_{0.05}$= 1.58, 3.04, 2.63, 2.6 and 2.6 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.1.3. Interaction effect of sulphur and boron doses

Plant height (cm) was not significantly affected by the interaction of sulphur and boron doses which is shown in Table 1. At 30 DAS, highest plant height (33.11 cm) was recorded from the combination of 37.2 kg ha^{-1} sulphur and 0 kg ha^{-1} boron (S_3B_0) which was statistically similar (30 cm) with S_3B_1 and the lowest plant height (20.11 cm) was obtained from the combination of 0 kg ha^{-1} sulphur and 0.875 kg ha^{-1} boron (S_0B_1) which was statistically similar with S_0B_0, S_0B_2, S_0B_3, S_1B_0, S_1B_2, S_1B_3 and S_2B_3. Combination of 37.2 kg ha^{-1} sulphur and 0 kg ha^{-1} boron (S_3B_0) scored the highest plant height (103 cm) at 45 DAS which was statistically similar with S_2B_0, S_3B_1, S_3B_2 and S_3B_3. The lowest plant height (90.45 cm) was recorded at the combination of 0 kg ha^{-1} sulphur and 0.875 kg ha^{-1} boron (S_0B_1) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_1 and S_2B_3. At 60 DAS, 75 DAS and at harvest highest plant height (113.48, 113.18 and 113.18 cm) was obtained from the combination of 37.2 kg ha^{-1} sulphur and 1.75 kg ha^{-1} boron (S_3B_2) which was statistically similar with S_1B_0, S_2B_0, S_2B_2, S_3B_0, S_3B_1 and S_3B_3. On the other hand the lowest plant height was observed at control or at the combination of 0 kg ha^{-1} Sulphur and 0 kg ha^{-1} boron (S_0B_0) which was statistically similar with S_0B_1, S_0B_2, S_0B_3, S_1B_1, S_1B_2, S_1B_3, S_2B_1 and S_2B_3.

Table 1. Interaction effect of sulphur and boron doses on plant height (cm) at 30, 45, 60, 75 DAS and at harvest

Treatment Combination	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
S_0B_0	20.78 h	90.89 ef	102.73 f	103.08 f	102.96 f
S_0B_1	20.11 h	94.33 d-f	105.60 ef	105.34 ef	105.31 ef
S_0B_2	20.67 h	93.89 d-f	104.85 ef	104.73 ef	104.59 ef
S_0B_3	21.00 gh	90.45 f	105.85 d-f	105.74 d-f	105.66 d-f
S_1B_0	21.22 gh	94.78 c-f	108.73 a-e	108.51 a-e	108.30 a-e
S_1B_1	24.78 c-f	96.34 c-f	106.5 c-f	106.15 c-f	106.11 c-f
S_1B_2	22.33 e-h	94.89 c-f	105.64 ef	105.90 c-f	105.77 d-f
S_1B_3	21.67 f-h	93.89 d-f	107.12 b-f	107.37 b-f	107.22 b-f
S_2B_0	25.3 c-e	98.89 a-d	109.01 a-e	108.49 a-e	108.49 a-e
S_2B_1	24.15 d-g	93.56 d-f	107.25 b-f	106.99 b-f	106.99 b-f
S_2B_2	25.78 cd	96.66 b-e	111.06 a-d	110.71 a-d	110.71 a-d
S_2B_3	22.84 d-h	93.78 d-f	107.32 b-f	107.03 b-f	107.01 b-f
S_3B_0	33.11 a	103.00 a	111.38 a-c	111.06 a-c	111.02 a-c
S_3B_1	30.00 ab	98.78 a-d	109.29 a-e	109.09 a-e	109.09 a-e
S_3B_2	29.00 b	102.67 ab	113.48 a	113.18 a	113.18 a
S_3B_3	27.89 bc	100.67 a-c	112.09 ab	111.76 ab	111.75 ab
$LSD_{(0.05)}$	3.17	6.08	5.26	5.2	5.21
CV (%)	7.8	3.8	2.9	2.9	2.9

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.1.2 Leaf number

4.1.2.1 Effect of sulphur doses

Leaf number was not significantly affected by sulphur doses at 30, 45, 60 and 75 DAS but significant at harvest (Appendix V and Figure 3). At 30 DAS, maximum leaf number (11.03) was recorded at 18.6 kg ha^{-1} sulphur dose which was statistically similar (10.69) with 37.2 kg ha^{-1} sulphur dose. Minimum leaf number (9.83) was observed at 27.9 kg ha^{-1} sulphur dose which was statistically similar (9.94) with 0 kg ha^{-1} sulphur dose or at control. On 45 DAS and 60 DAS all the treatments scored statistically similar result. On 45 DAS and 60 DAS, the maximum leaf number (38.7 and 82.58) was observed at 18.6 kg ha^{-1} sulphur dose. On 45 DAS, minimum leaf number (36.03) was recorded at control or 0 $kgha^{-1}$ sulphur. On the other hand, at 60 DAS, minimum leaf number (79.22) was recorded at 27.9 kg ha^{-1} sulphur dose. In case of 75 DAS, maximum leaf number (29.47) was recorded at control or 0 kg ha^{-1} sulphur dose which showed statistically similar result with 37.2 kg ha^{-1} (29.11) and 27.9 kg ha^{-1} (25.89) sulphur doses. On the other hand, 18.6 kg ha^{-1} sulphur dose scored the minimum leaf number (25.47) which showed the statistically similar result with 27.9 kg ha^{-1} and 37.2 kg ha^{-1} sulphur doses. At harvest, maximum leaf number (11) was recorded at 37.2 kg ha^{-1} sulphur dose which was statistically similar (10.42) with 0 kg ha^{-1} sulphur dose or at control. On the other hand, minimum leaf number (8.25) was observed at 18.6 kg ha^{-1} sulphur dose which was statistically similar (8.42) with 27.9 kg ha^{-1} sulphur dose.

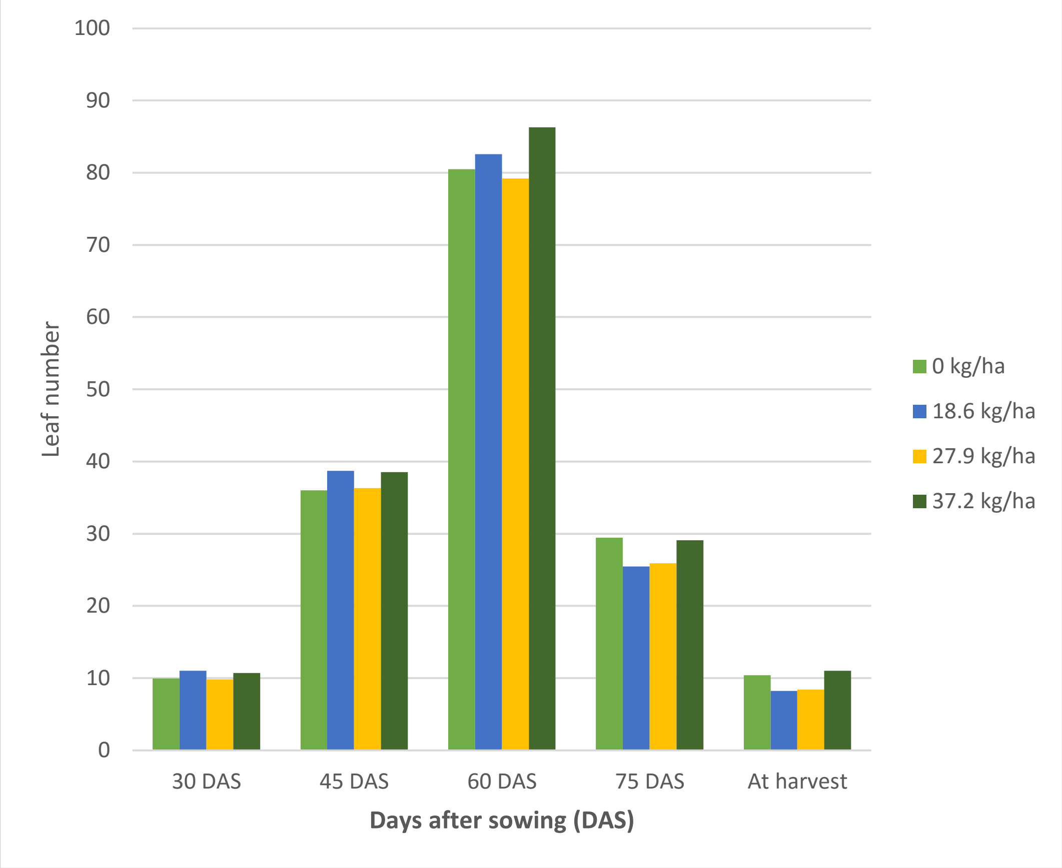

Figure 3. Effect of sulphur doses on leaf number of rapeseed plant at different DAS ($LSD_{0.05}$= 1.04, 4.38, 9.01, 3.64 and 1.33 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.2.2 Effect of boron doses

Effect of boron doses on leaf number of rapeseed plant was not significant throughout the growing period (Appendix V and Figure 4). All the treatments were scored statistically same result throughout the growing period. At 30 DAS, maximum leaf number (10.61) was recorded at 1.75 kg ha^{-1} boron dose and minimum leaf number (10.17) was observed at 2.625 kg ha^{-1} boron dose. On 45 DAS, maximum leaf number (40.06) was recorded at 2.625 kg ha^{-1} boron dose and minimum leaf number (35.75) was recorded at 0.875 kg ha^{-1} boron dose. In case of 60 DAS, maximum leaf number (83.22) was recorded at 2.625 kg ha^{-1} boron dose and minimum leaf number (81.03) was observed at 1.75 kg ha^{-1} boron dose. At 75 DAS, maximum leaf number (28.39) was recorded at control or at 0 kg ha^{-1} boron dose and minimum leaf number (25.78) was observed at 1.75 kg ha^{-1} boron dose. At harvest, maximum leaf number (9.83) was recorded at 2.625 kg ha^{-1} boron dose and minimum leaf number (9.17) was observed at 0.875 kg ha^{-1} boron dose.

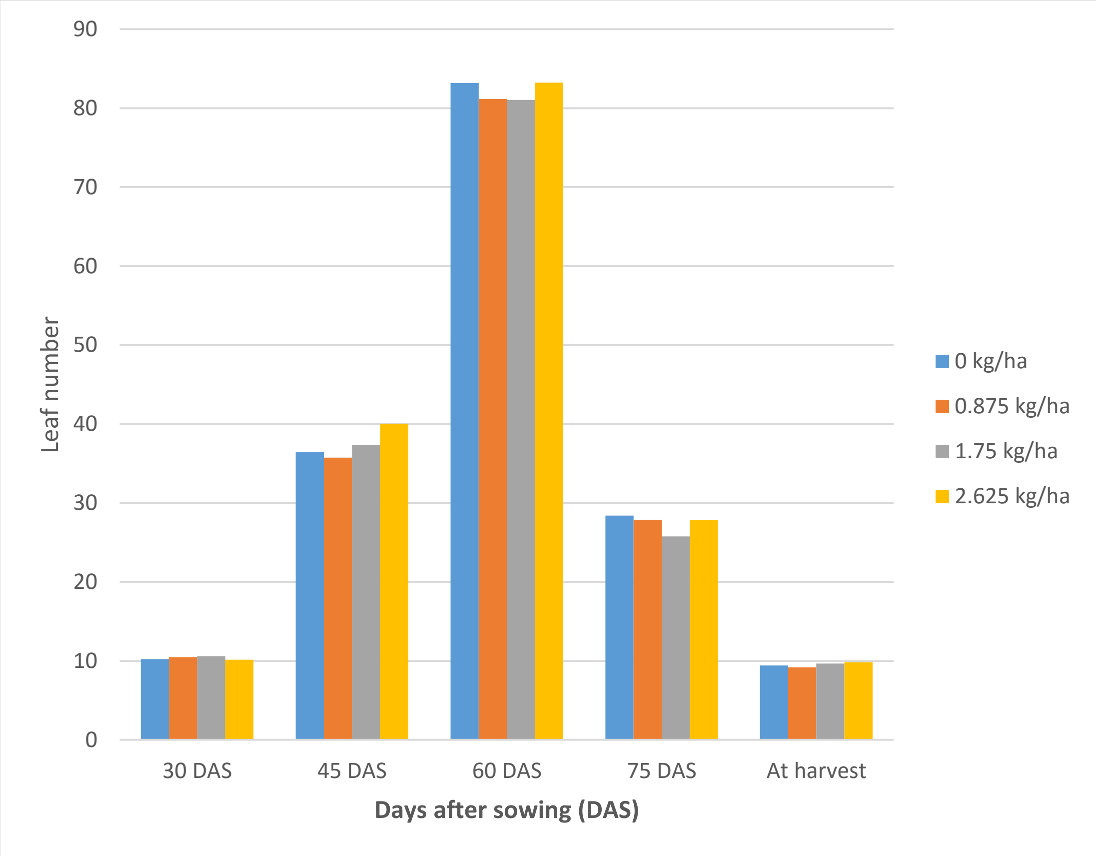

Figure 4. Effect of boron doses on leaf number of rapeseed plant at different DAS ($LSD_{0.05}$= 1.58, 3.04, 2.63, 2.6 and 2.6 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.2.3. Interaction effect of sulphur and boron doses

Leaf number was not significantly affected by the interaction of sulphur and boron doses which is shown in Table 2. At 30 DAS, maximum leaf number (11.55) was recorded at the combination of 18.6 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_1B_1) which was statistically similar with S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_2, S_1B_3, S_2B_0, S_2B_2, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. Minimum leaf number (9.11) was observed at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose or at control which was statistically similar with S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_1, S_3B_2 and S_3B_3. On 45 DAS, maximum leaf number (42.56) was recorded at the combination of 0 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_0B_3) which was statistically similar with S_0B_1, S_0B_2, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. Minimum leaf number (31.78) was observed at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose or at control which was statistically similar with S_0B_1, S_0B_2, S_1B_0, S_1B_1, S_1B_2, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1 and S_3B_3. In case of 60 DAS, maximum leaf number (89.89) was recorded at the combination of 18.6 kgha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_1B_3) and minimum leaf number (72.22) was observed at the combination of 27.9 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_2B_3). All the treatments showed statistically same result. At 75 DAS, maximum leaf number (32.67) was recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_3B_1) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_3, S_2B_0, S_2B_1, S_3B_0 and S_3B_3. On the other hand, minimum leaf number (20.22) was observed at the combination of 18.6 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_1B_1) which was statistically similar with S_0B_3, S_1B_0, S_1B_2, S_2B_2, S_2B_3 and S_3B_2. At harvest, maximum leaf number (11.67) was observed at the combination of 0 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_0B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. On the other hand minimum leaf number (6.33) was observed at the combination of 18.6 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_1B_1) which was statistically similar with S_1B_0, S_2B_0, S_2B_1, S_2B_2 and S_2B_3.

Table 2. Interaction effect of sulphur and boron doses on leaf number at 30, 45, 60, 75 DAS and at harvest

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
S_0B_0	9.11 c	31.78 b	80.78 a	30.00 a-d	9.33 a-c
S_0B_1	10.56 a-c	34.89 ab	78.00 a	29.22 a-d	10.33 a-c
S_0B_2	10.11 a-c	34.89 ab	79.67 a	31.22 ab	11.67 a
S_0B_3	10 a-c	42.56 a	83.56 a	27.44 a-f	10.33 a-c
S_1B_0	10.33 a-c	37.67 ab	81.11 a	26.67 a-f	8.67 cd
S_1B_1	11.67 a	38.00 ab	79.78 a	20.22 f	6.33 d
S_1B_2	11.55 a	37.89 ab	79.55 a	23.89 c-f	9.00 bc
S_1B_3	10.57 a-c	41.22 a	89.89 a	31.11 a-c	9.00 bc
S_2B_0	10.22 a-c	38.22 ab	82.22 a	27.55 a-e	8.33 cd
S_2B_1	9.44 bc	33.89 ab	80.67 a	29.44 a-d	8.67 cd
S_2B_2	9.67 a-c	35.11 ab	81.78 a	24.89 b-f	8.00 cd
S_2B_3	10.00 a-c	38.00 ab	72.22 a	21.67 ef	8.67 cd
S_3B_0	11.22 ab	38.00 ab	88.67 a	29.33 a-d	11.33 ab
S_3B_1	10.33 a-c	36.22 ab	86.22 a	32.67 a	11.33 ab
S_3B_2	11.11 a-c	41.44 a	83.11 a	23.11 d-f	10.00 a-c
S_3B_3	10.11 a-c	38.44 ab	87.22 a	31.33 ab	11.33 ab
$LSD_{(0.05)}$	2.08	8.75	18.03	7.28	2.65
CV (%)	12	14	13.2	15.9	16.7

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.1.3 Dry matter accumulation

4.1.3.1 Effect of sulphur doses

Dry matter (g) production was not significantly affected by sulphur doses at 30 DAS but significant at 45, 60 and 75 DAS (Appendix V and Figure 5). At 30 DAS, maximum weight (0.68 g) was gained at 18.6 kg ha^{-1} sulphur dose and minimum dry matter weight (0.63 g) was recorded at 37.2 kg ha^{-1} sulphur dose. All the treatments showed statistically same result. On 45, 60 and 75 DAS, maximum dry matter accumulation (6.8, 13.06 and 15.14 g) was recorded at 37.2 kg ha^{-1} sulphur dose. At 45 DAS, the result was statistically similar (6.52) with the application of 27.9 kg ha^{-1} sulphur. At 45, 60 and 75 DAS minimum dray matter production (5.04, 9.76 and 12.54 g) was observed at 0 kg ha^{-1} sulphur dose. On 60 DAS, the result was statistically similar (10.2 g) with 18.6 kg ha^{-1} sulphur dose. In case of 75 DAS, the result was statistically similar with 18.6 kg ha^{-1} (12.82 g) and 27.9 kg ha^{-1} (13.09 g) sulphur doses. Nad and Goswami (1983), also found the similar result.

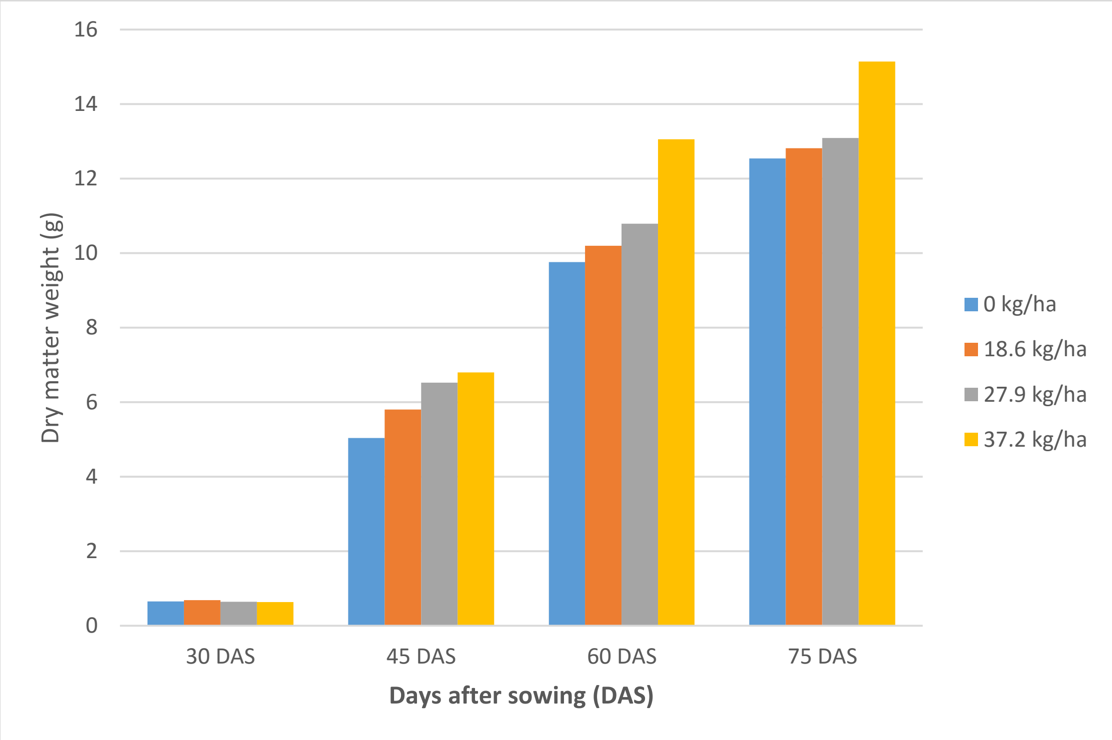

Figure 5. Effect of sulphur doses on dry matter accumulation of rapeseed plant at different DAS (LSD$_{0.05}$= 0.059, 0.75, 0.81 and 0.71 at 30, 45, 60 and 75 DAS respectively)

4.1.3.2 Effect of boron doses

Dry matter accumulation (g) was not significantly affected by boron doses at any stage of life cycle of rapeseed plant (Appendix V and Figure 6). Throughout the life cycle all the treatments showed statistically same result. At 30 DAS, maximum dry matter weight (0.67 g) was recorded at 0.875 kg ha^{-1} boron dose and minimum dry matter weight (0.63 g) was observed at 0 kg ha^{-1} boron dose.

On 45 DAS, maximum dry matter production (6.38 g) was recorded at 2.625 kg ha^{-1} boron dose and minimum dry matter production (5.79 g) was observed at 1.75 kg ha^{-1} boron dose. In case of 60 DAS, maximum dry matter accumulation (11.14 g) was recorded at 0 kg ha^{-1} boron dose and minimum dry matter accumulation (10.74 g) was observed at 0.875 kg ha^{-1} boron dose. At 75 DAS, maximum dry matter (13.61 g) was produced at 1.75 kg ha^{-1} boron dose and minimum dry matter (13.01 g) was produced at 0.875 kg ha^{-1} boron dose.

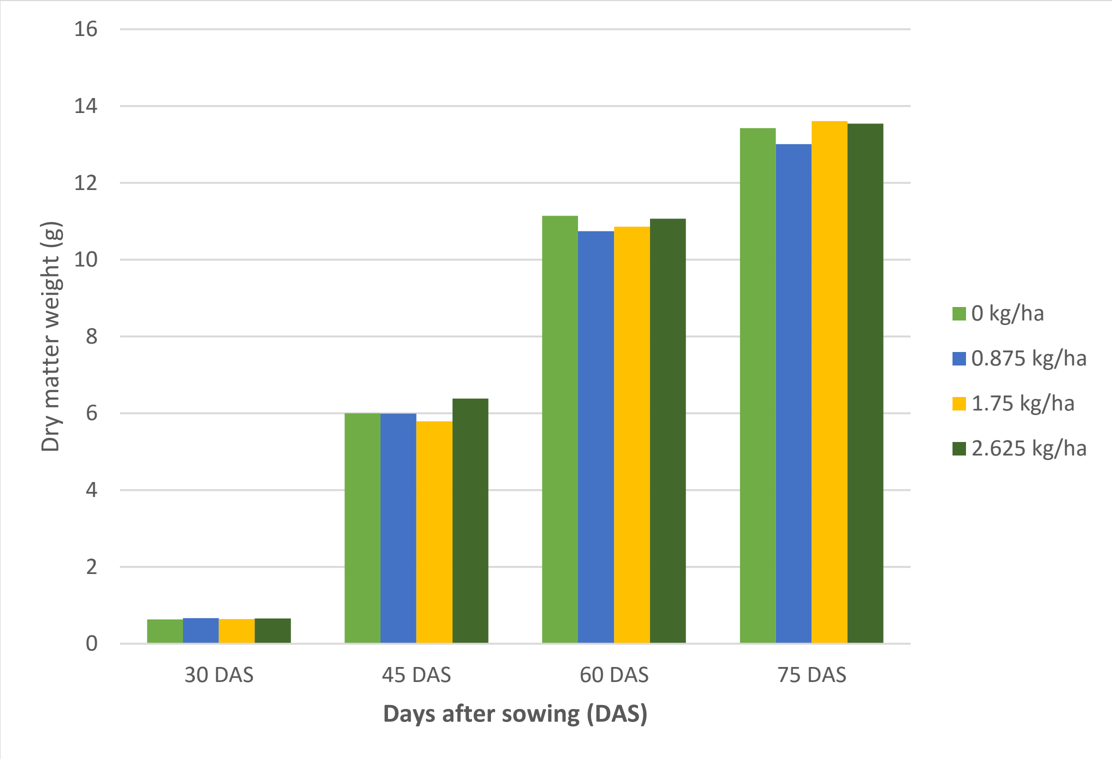

Figure 6. Effect of boron doses on dry matter (g) accumulation of rapeseed plant at different DAS ($LSD_{0.05}$= 0.059, 0.75, 0.81 and 0.71 at 30, 45, 60 and 75 DAS respectively)

4.1.3.3. Interaction effect of sulphur and boron doses

Dry matter accumulation (g) was not significantly affected by the interaction of sulphur and boron doses at 30, 45 and 60 DAS but significant at 75 DAS which is shown in Table 3. At 30 DAS, maximum dry matter (0.72 g) accumulation was recorded at the combination of 18.6 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_1B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3,

S_1B_0, S_1B_1, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1 and S_3B_3. Minimum dry matter (0.58 g) accumulation was observed at the combination of 37.2 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_3B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_1B_0, S_1B_1, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1 and S_3B_3. On 45 DAS, maximum dry matter (7.83 g) production was recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3) which was statistically similar with S_2B_1, S_2B_2, S_2B_3, S_3B_0 and S_3B_2. Minimum dry matter (4.59 g) production was recorded at the combination of 0 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_0B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_2, S_1B_3 and S_2B_0. At 60 DAS and 75 DAS, maximum dry matter (13.84 and 16.8 g) was produced at the combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3). In case of 60 DAS, the result was statistically similar with S_3B_0 and S_3B_1. In case of 75 DAS, the result was statistically similar with S_3B_0. On the other hand, minimum dry matter (9.62 and 12.07 g) was produced at the combination of 0 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_0B_3). In case of 60 DAS, the result was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2 and S_2B_3. In case of 75 DAS, the result was statistically similar with S_0B_0, S_0B_1, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2 and S_2B_3.

Table 3. Interaction effect of sulphur and boron doses on dry matter accumulation (g) at 30, 45, 60 and 75 DAS

Treatment Combination	30 DAS	45 DAS	60 DAS	75 DAS
S_0B_0	0.63 ab	5.13 d-f	9.94 e	12.24 e
S_0B_1	0.62 ab	4.97 ef	9.77 e	12.13 e
S_0B_2	0.62 ab	4.59 f	9.71 e	13.72 cd
S_0B_3	0.71 a	5.47 c-f	9.62 e	12.07 e
S_1B_0	0.7 ab	6.21 b-e	10.06 e	12.85 de
S_1B_1	0.67 ab	6.27 b-e	9.80 e	12.81 de
S_1B_2	0.72 a	5.06 d-f	10.62 de	12.99 c-e
S_1B_3	0.64 ab	5.65 b-f	10.31 e	12.65 de
S_2B_0	0.6 ab	5.95 b-f	10.83 de	13.13 c-e
S_2B_1	0.7 ab	6.51 a-d	10.86 de	13.24 c-e
S_2B_2	0.63 ab	7.05 ab	10.97 c-e	13.32 c-e
S_2B_3	0.64 ab	6.56 a-d	10.50 e	12.67 de
S_3B_0	0.60 ab	6.7 a-c	13.73 ab	15.51 ab
S_3B_1	0.69 ab	6.21 b-e	12.54 a-c	13.86 cd
S_3B_2	0.58 b	6.44 a-e	12.14 b-d	14.4 bc
S_3B_3	0.65 ab	7.83 a	13.84 a	16.8 a
SE	0.041	0.52	0.56	0.49
$LSD_{(0.05)}$	0.12	1.51	1.63	1.42
CV (%)	10.9	15	8.9	6.4

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.1.4 Crop Growth Rate (CGR)

4.1.4.1 Effect of sulphur doses

Crop growth rate (CGR) is a measure of the increase in size, mass or number of crops over a period of time (Appendix V and Figure 7). The increase can be plotted as a logarithmic or exponential curve in many cases. CGR was significantly affected by sulphur doses at 30-45 DAS and 45-60 DAS but not significant at 60-75 DAS (Appendix V and Figure 7). At 30-45 DAS, highest CGR (0.411 g plant^{-1} day^{-1}) was recorded at 37.2 kgha^{-1} sulphur dose which was statistically similar (0.392 g plant^{-1} day^{-1}) with 27.9 kg ha^{-1} sulphur dose and lowest CGR (0.293 g plant^{-1} day^{-1}) was recorded at 0 kgha^{-1} sulphur dose which was statistically similar (0.341 g plant^{-1} day^{-1}) with 18.6 kg ha^{-1} sulphur dose. On 45-60 DAS, highest CGR (0.418 g plant^{-1} day^{-1}) was recorded at 37.2 kg ha^{-1} sulphur dose and lowest CGR (0.285 g plant^{-1} day^{-1}) was observed at 27.9 kg ha^{-1} sulphur dose which was statistically similar (0.315 and 0.293 g plant^{-1} day^{-1}) with both 0 kg ha^{-1} and 18.6 kg ha^{-1} sulphur doses. At 60-75 DAS, highest CGR (0.185 g plant^{-1} day^{-1}) was recorded at 0 kg ha^{-1} sulphur dose and lowest CGR (0.139 g plant^{-1} day^{-1}) was observed at 37.2 kg ha^{-1} sulphur dose. All the treatments showed statistically same result.

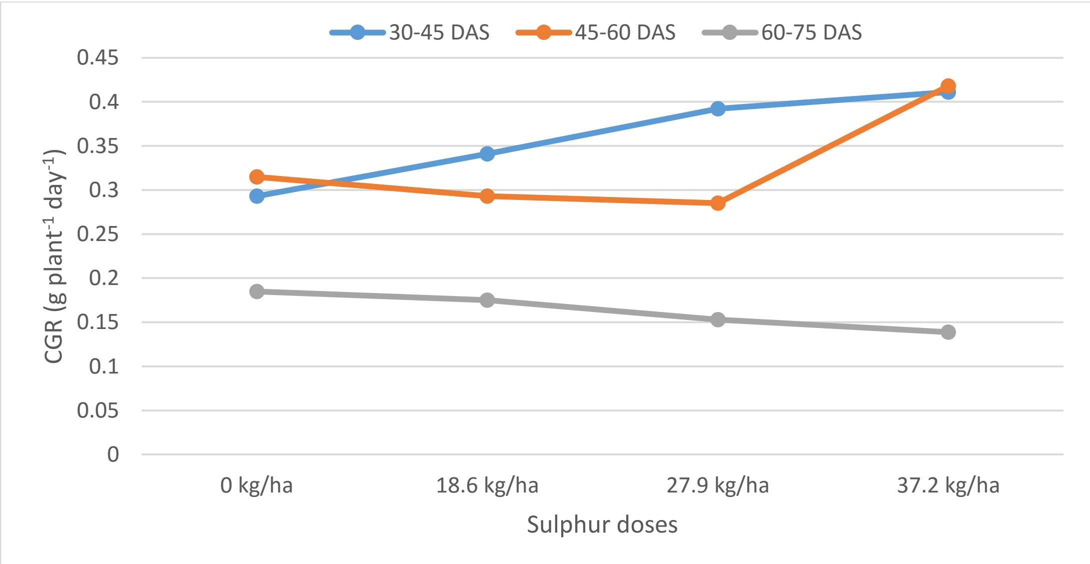

Figure 7. Effect of sulphur doses on CGR of rapeseed plant at different DAS ($LSD_{0.05}$= 0.05, 0.07 and 0.06 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.4.2 Effect of boron doses

CGR was not significantly affected by boron doses throughout the lifecycle of rapeseed plant (Appendix V and Figure 8). At 30-45 DAS, highest CGR (0.381 g plant^{-1} day^{-1}) was recorded at 2.625 kg ha^{-1} boron dose and lowest CGR (0.343 g plant^{-1} day^{-1}) was recorded at 1.75 kg ha^{-1} boron dose. On 45-60 DAS, highest

CGR (0.343) was recorded at 0 kg ha^{-1} boron dose and lowest CGR (0.313 g $plant^{-1}$ day^{-1}) was observed at 2.625 kg ha^{-1} boron dose. At 60-75 DAS, highest CGR (0.183 g $plant^{-1}$ day^{-1}) was recorded at 1.75 kg ha^{-1} boron dose and lowest CGR (0.151 g $plant^{-1}$ day^{-1}) was observed at 0.875 kg ha^{-1} boron dose. All the treatments showed statistically same result throughout the lifecycle.

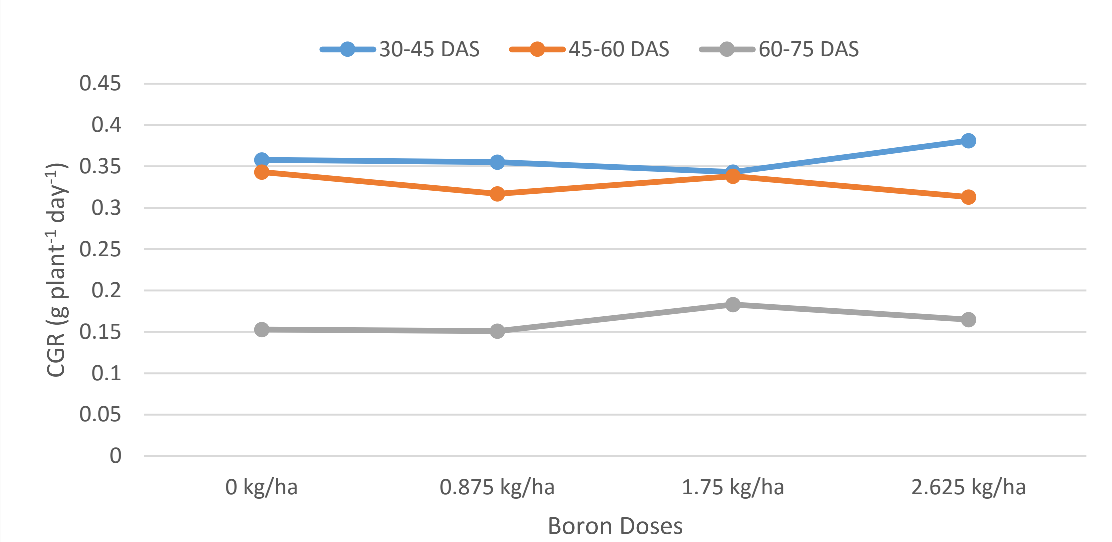

Figure 8. Effect of boron doses on CGR of rapeseed plant at different DAS ($LSD_{0.05}$= 0.05, 0.07 and 0.06 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.3.3. Interaction effect of sulphur and boron doses

CGR was not significantly affected by the interaction of sulphur and boron doses throughout the lifecycle which is shown in Table 4. At 30-45 DAS, highest CGR (0.479 g $plant^{-1}$ day^{-1}) was recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3) which was statistically similar with S_2B_1, S_2B_2, S_2B_3, S_3B_0 and S_3B_2. Lowest CGR (0.265 g $plant^{-1}$ day^{-1}) was observed at the combination of 0 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_0B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_2, S_1B_3 and S_2B_0. At 45-60 DAS, highest CGR (0.468 g $plant^{-1}$ day^{-1}) was recorded at the combination of 37.2 $kgha^{-1}$ sulphur dose and 0 kg ha^{-1} boron dose (S_3B_0) which was statistically similar with S_1B_2, S_2B_0, S_3B_1, S_3B_2 and S_3B_3. Lowest CGR (0.236 g $plant^{-1}$ day^{-1}) was observed at the combination of 18.6 kg ha^{-1} sulphur dose and 0.875 $kgha^{-1}$ boron dose (S_1B_1) which was statistically similar with

S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3 and S_3B_2. At 60-75, highest CGR (0.267 g plant^{-1} day^{-1}) was recorded at the combination of 0 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_0B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_2 and S_3B_2. Lowest CGR (0.088 g plant^{-1} day^{-1}) was observed at the combination of 37.2 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_3B_1) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_2 and S_3B_3.

Table 4. Interaction effect of sulphur and boron doses on crop growth rate (g plant^{-1} day^{-1}) at 30-45, 45-60 and 60-75 DAS

Treatment Combination	30-45 DAS	45-60 DAS	60-75 DAS
S_0B_0	0.300 d-f	0.321 b-d	0.154 ab
S_0B_1	0.290 ef	0.320 b-d	0.157 ab
S_0B_2	0.265 f	0.341 a-d	0.267 a
S_0B_3	0.317 c-f	0.277 b-d	0.164 ab
S_1B_0	0.368 b-e	0.256 cd	0.186 ab
S_1B_1	0.373 b-e	0.236 d	0.200 ab
S_1B_2	0.289 ef	0.371 a-d	0.158 ab
S_1B_3	0.334 b-f	0.311 b-d	0.156 ab
S_2B_0	0.357 b-f	0.326 a-d	0.153 ab
S_2B_1	0.387 a-e	0.290 b-d	0.159 ab
S_2B_2	0.428 ab	0.261 cd	0.157 ab
S_2B_3	0.395 a-d	0.262 cd	0.144 ab
S_3B_0	0.406 a-c	0.468 a	0.119 b
S_3B_1	0.368 b-e	0.421 ab	0.088 b
S_3B_2	0.391 a-d	0.380 a-d	0.150 ab
S_3B_3	0.479 a	0.401 a-c	0.197 ab
$LSD_{(0.05)}$	0.1	0.146	0.124
CV(%)	16.6	26.8	45.5

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.1.5 Relative growth rate (RGR)

4.1.5.1 Effect of sulphur doses

Relative growth rate (RGR) is the increase of materials per unit of plant materials per unit of time (Appendix V and Figure 9). CGR was significantly affected by sulphur doses at 30-45 DAS and 60-75 DAS but not significant at 45-60 DAS (Appendix V and Figure 7). At 30-45 DAS, highest RGR (0.159 g g^{-1} day^{-1}) was recorded at 37.2 kg ha^{-1} sulphur dose which was statistically similar (0.154 g g^{-1} day^{-1}) with 27.9 kg ha^{-1} sulphur dose and lowest RGR (0.137 g g^{-1} day^{-1}) was recorded at 0 kg ha^{-1} sulphur dose which was statistically similar (0.142 g g^{-1} day^{-1}) with 18.6 $kgha^{-1}$ sulphur dose. On 45-60 DAS, highest RGR (0.045) was recorded at 0 kg ha^{-1} sulphur dose which was statistically similar (0.044 and 0.038 g g^{-1} day^{-1}) with both 37.2 kg ha^{-1} and 18.6 kg ha^{-1} sulphur doses. On the other hand, lowest RGR (0.034 g g^{-1} day^{-1}) was observed at 27.9 kg ha^{-1} sulphur dose which was statistically similar (0.038 g g^{-1} day^{-1}) with 18.6 kg ha^{-1} sulphur dose. At 60-75 DAS, highest RGR (0.017 g g^{-1} day^{-1}) was recorded at 0 kg ha^{-1} sulphur dose which was statistically similar (0.015 and 0.013 g g^{-1} day^{-1}) with both 18.6 kg ha^{-1} and 27.9 kg ha^{-1} sulphur doses. On the other hand, lowest RGR (0.01 g g^{-1} day^{-1}) was observed at 37.2 kg ha^{-1} sulphur dose which was statistically similar (0.013 g g^{-1} day^{-1}) with 27.9 kg ha^{-1} sulphur dose.

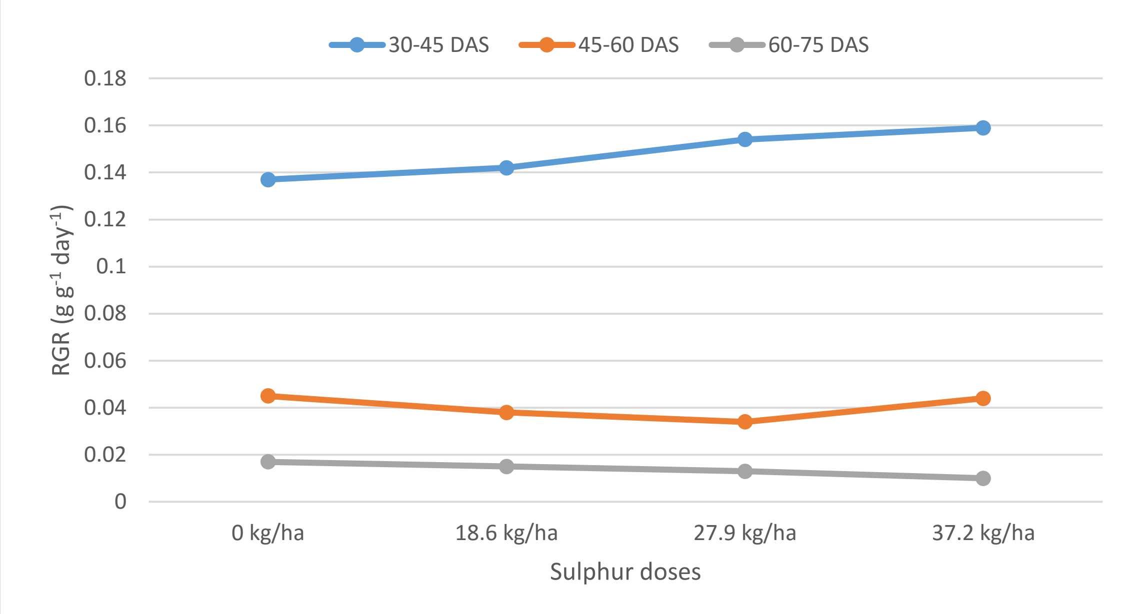

Figure 9. Effect of sulphur doses on RGR of rapeseed plant at different DAS ($LSD_{0.05}$= 0.01, 0.009 and 0.004 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.5.2 Effect of boron doses

RGR was not significantly affected by boron doses throughout the lifecycle of rapeseed plant (Appendix V and Figure 10). At 30-45 DAS, highest RGR (0.315 g g^{-1} day^{-1}) was recorded both at 0 kg ha^{-1} and 2.625 kg ha^{-1} boron doses and lowest RGR (0.146) was recorded both at 0.875 kg ha^{-1} and 1.75 $kgha^{-1}$ boron doses. On 45-60 DAS, highest RGR (0.043 g g^{-1} day^{-1}) was recorded at 1.75 kg ha^{-1} boron dose and lowest RGR (0.037 g g^{-1} day^{-1}) was observed at 2.625 kg ha^{-1} boron dose. At 60-75 DAS, highest RGR (0.015 g g^{-1} day^{-1}) was recorded at 1.75 kg ha^{-1} boron dose and lowest RGR (0.013 g g^{-1} day^{-1}) was observed both at 0 kg ha^{-1} and 0.875 kg ha^{-1} boron doses. All the treatments showed statistically same result throughout the lifecycle.

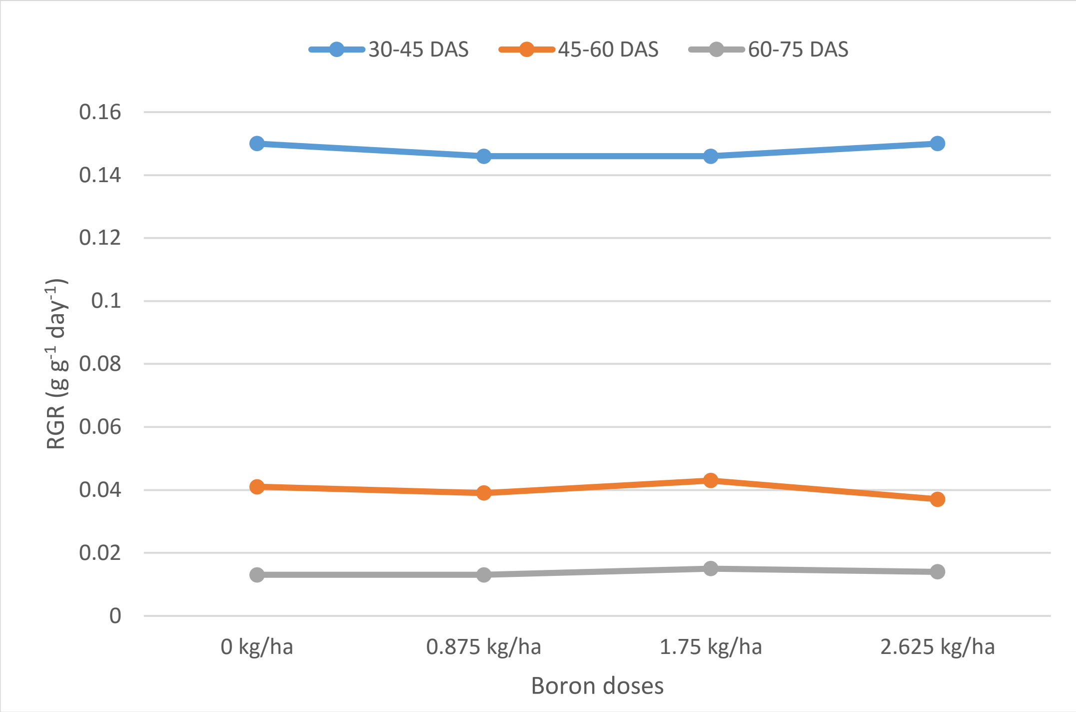

Figure 10. Effect of boron doses on RGR of rapeseed plant at different DAS ($LSD_{0.05}$= 0.01, 0.009 and 0.004 at 30-45, 45-60 and 60-75 DAS respectively)

4.1.5.3. Interaction effect of sulphur and boron doses

RGR was not significantly affected by the interaction of sulphur and boron doses throughout the lifecycle which is shown in Table 5. At 30-45 DAS, highest RGR (0.166) was recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3) which was statistically similar with S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1 and S_3B_2. Lowest RGR (0.13 g g^{-1} day^{-1}) was observed at the combination of 18.6 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_1B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_3 and S_2B_1. At 45-60 DAS, highest RGR (0.05 g g^{-1} day^{-1}) was recorded both at the combination of 0 kg ha^{-1} sulphur & 1.75 kg ha^{-1} boron dose (S_0B_2) and 18.6 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_1B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_0, S_1B_3, S_2B_0, S_2B_1, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. Lowest RGR (0.03) was observed both at the combination of 18.6 kg ha^{-1} sulphur dose & 0.875 kg ha^{-1} boron dose (S_1B_1) and 27.9 kg ha^{-1} sulphur and 1.75 kg ha^{-1} boron dose (S_2B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3,

S_1B_0, S_1B_3, S_2B_0, S_2B_1, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. At 60-75, highest RGR (0.023 g g^{-1} day^{-1}) was recorded at the combination of 0 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_0B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_0, S_1B_1 and S_1B_3. Lowest RGR (0.007 g g^{-1} day^{-1}) was observed at the combination of 37.2 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_3B_1) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_0, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_2 and S_3B_3.

Table 5. Interaction effect of sulphur and boron doses on relative growth rate (g g^{-1} day^{-1}) at 30-45, 45-60 and 60-75 DAS

Treatments	30-45 DAS	45-60 DAS	60-75 DAS
S_0B_0	0.140 c-e	0.044 ab	0.014 a-c
S_0B_1	0.139 c-e	0.045 ab	0.014 a-c
S_0B_2	0.135 c-e	0.050 a	0.023 a
S_0B_3	0.134 c-e	0.040 ab	0.015 a-c
S_1B_0	0.145 b-e	0.033 ab	0.016 a-c
S_1B_1	0.149 a-e	0.030 b	0.018 ab
S_1B_2	0.130 e	0.050 a	0.013 bc
S_1B_3	0.146 a-e	0.040 ab	0.014 a-c
S_2B_0	0.153 a-d	0.040 ab	0.013 bc
S_2B_1	0.148 a-e	0.034 ab	0.013 bc
S_2B_2	0.161 ab	0.030 b	0.013 bc
S_2B_3	0.155 a-c	0.032 ab	0.013 bc
S_3B_0	0.161 ab	0.048 ab	0.008 c
S_3B_1	0.146 a-d	0.047 ab	0.007 c
S_3B_2	0.161 ab	0.043 ab	0.011 bc
S_3B_3	0.166 a	0.037 ab	0.013 bc
$LSD_{(0.05)}$	0.02	0.019	0.009
CV (%)	8.1	28.2	39.2

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.1.6 Number of primary branches

4.1.6.1 Effect of sulphur doses

Number of primary branches plant^{-1} was not significantly affected by sulphur doses throughout the life cycle (Appendix V and Figure 11). At 30 DAS, maximum number of primary branches plant^{-1} (3.25) were recorded at 0 kg ha^{-1} sulphur dose and minimum number of primary branches (2.83) were recorded at 18.6 kg ha^{-1} sulphur dose. On 45 DAS, maximum number of primary branches (9.25) were recorded at 18.6 kg ha^{-1} sulphur dose and minimum number of primary branches (8.75) were recorded at 37.2 kg ha^{-1} sulphur dose. In case of 60 DAS, maximum number of primary branches (9.83) were recorded at 18.6 kg ha^{-1} sulphur dose and minimum number of primary branches (9.08) were recorded at 27.9 kg ha^{-1} sulphur dose. At 75 DAS, maximum number of primary branches (9.83) were recorded at 18.6 kg ha^{-1} sulphur dose and minimum number of primary branches (9.17) were recorded both at 27.9 kgha^{-1} & 37.2 kg ha^{-1} sulphur dose. At 45, 60 and 75 DAS all the treatments showed statistically same result. At harvest, maximum number of primary branches (9.92) were recorded at 18.6 kg ha^{-1} sulphur dose which was statistically similar (9.58) with 0 kg ha^{-1} sulphur dose and minimum number of primary branches (9.17) were recorded both at 27.9 kg ha^{-1} & 37.2 kg ha^{-1} sulphur dose which was statistically similar with 0 kg ha^{-1} sulphur dose. Chauhan *et al.* (1996) found the opposite result. They observed that each successive increase in S level from 0-50 kg ha^{-1} significantly increased the number of branches plant^{-1}.

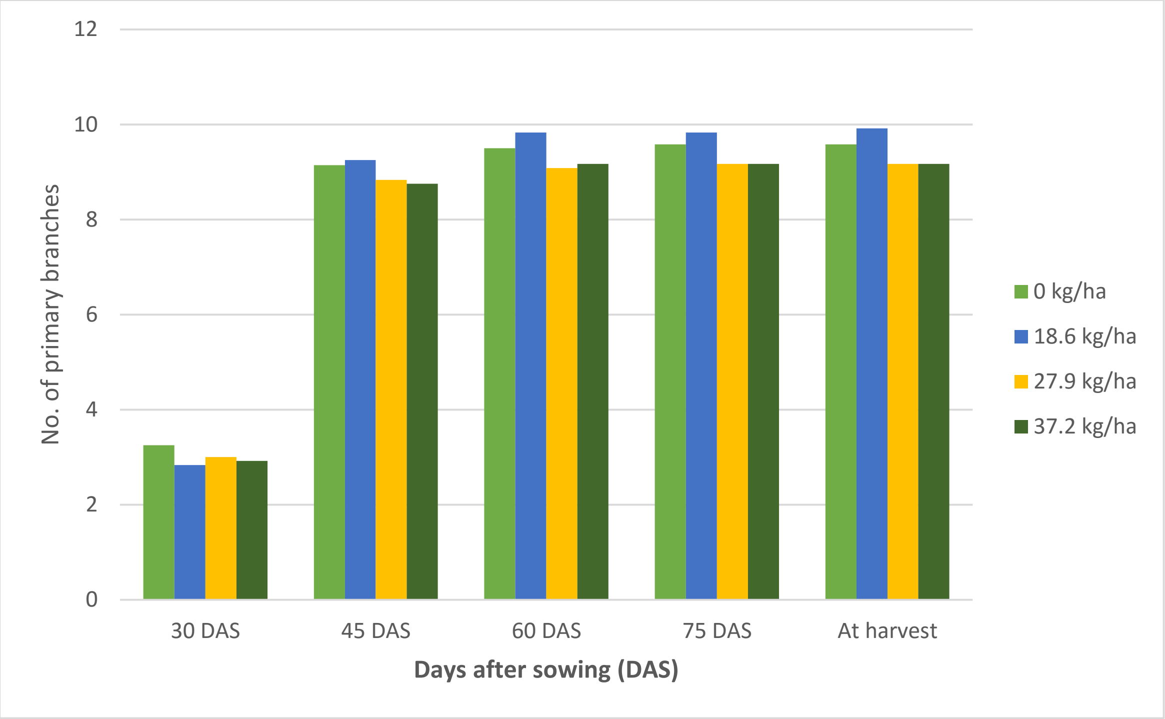

Figure 11. Effect of sulphur doses on primary branch number of rapeseed plant at different DAS ($LSD_{0.05}$= 1.46, 1.27, 1.27, 1.37 and 1.36 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.6.2 Effect of boron doses

Number of primary branches was not significantly affected by boron doses throughout the life cycle (Appendix V and Figure 12). At 30 DAS, maximum number of primary branches (3.17) were recorded both at 0 kg ha^{-1} and 0.875 kg ha^{-1} boron doses and minimum number of primary branches (2.67) were recorded at 2.625 kg ha^{-1} boron dose. All the treatments showed statistically same result. On 45, 60 and 75 DAS, maximum number of primary branches (9.42, 9.75 and 9.83) were recorded at 0 kg ha^{-1} boron dose which was statistically similar with 1.75 kg ha^{-1} & 2.625 kg ha^{-1} boron doses; minimum number of primary branches (8.75, 9.08 and 9.08) were recorded at 0.875 kg ha^{-1} boron dose which was statistically similar with 1.75 kg ha^{-1} & 2.625 kg ha^{-1} boron doses. At harvest, maximum number of primary branches (9.83) were recorded at 0 kg ha^{-1} boron dose and minimum number of primary branches (9.17) were recorded at 0.875 kg ha^{-1} boron dose. All the treatments showed statistically similar result.

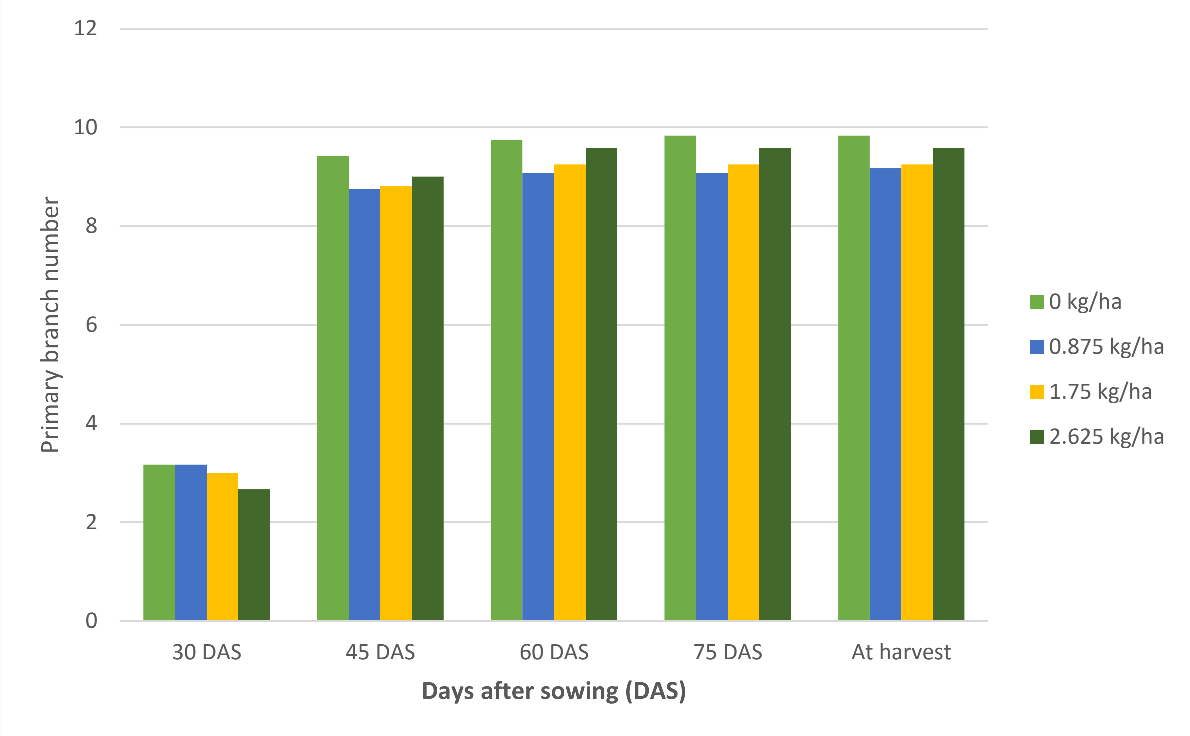

Figure 12. Effect of boron doses on primary branch number of rapeseed plant at different DAS ($LSD_{0.05}$= 1.46, 1.27, 1.27, 1.37 and 1.36 at 30, 45, 60 and 75 DAS and at harvest respectively)

4.1.6.3. Interaction effect of sulphur and boron doses

Number of primary branches was not significantly affected by the interaction of sulphur and boron doses throughout the lifecycle which is shown in Table 6. At 30 DAS, maximum number of primary branches (3.67) were recorded at the combination of 0 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_0B_1) which were statistically similar with S_0B_0, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. On the other hand, minimum number of primary branches (2) were observed at the combination of 18.6 kg ha^{-1} sulphur dose and 2.625 $kgha^{-1}$ boron dose (S_1B_3) which was statistically similar with S_0B_0, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. On 45 DAS, maximum number of primary branches (10) was recorded at the combination of 27.9 kg ha^{-1} sulphur doses and 0 kg ha^{-1} boron doses (S_2B_0) which was statistically similar with S_0B_0, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_3, S_3B_0 and

S_3B_3. On the other hand minimum number of primary branches (8.33) was observed at the combination of 27.9 kg ha^{-1} sulphur doses and 1.75 kg ha^{-1} boron doses (S_2B_2), 27.9 kg ha^{-1} sulphur doses and 2.625 kgha^{-1} boron doses (S_2B_3) and 37.2 kgha^{-1} sulphur doses and 0.875 kgha^{-1} boron doses (S_3B_1) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_2B_1, S_3B_0, S_3B_2 and S_3B_3. In case of 60 DAS, maximum number of primary branches (10.33) were recorded both at the combination of 18.6 kg ha^{-1} sulphur dose & 2.625 kgha^{-1} boron dose (S_1B_3) and 27.9 kgha^{-1} sulphur dose & 0 kgha^{-1} boron dose (S_2B_0) which were statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_3B_0 and S_3B_3. On the other hand, minimum number of primary branches (8.33) were observed at the combination of 27.9 kg ha^{-1} sulphur doses and 1.75 kg ha^{-1} boron doses (S_2B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_2, S_2B_1, S_2B_3, S_3B_0, S_3B_1 and S_3B_2. In case of 75 DAS, maximum number of primary branches (10.67) were recorded at the combination of 27.9 kgha^{-1} sulphur dose & 0 kgha^{-1} boron dose (S_2B_0) which were statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_3B_0 and S_3B_3. On the other hand, minimum number of primary branches (8.33) were observed at the combination of 27.9 kg ha^{-1} sulphur doses and 1.75 kg ha^{-1} boron doses (S_2B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_1, S_1B_2, S_2B_1, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_2. At harvest, maximum number of primary branches (10.67) were recorded at the combination of 27.9 kg ha^{-1} sulphur dose & 0 kg ha^{-1} boron dose (S_2B_0) which were statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_3B_0 and S_3B_3. On the other hand, minimum number of primary branches (8.33) were observed at the combination of 27.9 kg ha^{-1} sulphur doses and 1.75 kg ha^{-1} boron doses (S_2B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_2, S_2B_1, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_2.

Table 6. Interaction effect of sulphur and boron doses on primary branches at 30, 45, 60, 75 DAS and at harvest

Treatments	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
S_0B_0	3.33 ab	9.33 a-c	9.33 a-d	9.33 a-d	9.33 a-d
S_0B_1	3.67 a	8.67 bc	9.33 a-d	9.33 a-d	9.33 a-d
S_0B_2	3.00 ab	9.56 a-c	10.00 ab	10.33 ab	10.33 ab
S_0B_3	3.00 ab	9.00 a-c	9.33 a-d	9.33 a-d	9.33 a-d
S_1B_0	3.00 ab	9.33 a-c	10.00 ab	10.00 a-c	10.00 a-c
S_1B_1	3.33 ab	9.33 a-c	9.67 a-c	9.67 a-d	10.00 a-c
S_1B_2	3.00 ab	8.67 bc	9.33 a-d	9.33 a-d	9.33 a-d
S_1B_3	2.00 b	9.67 ab	10.33 a	10.33 ab	10.33 ab
S_2B_0	3.33 ab	10.00 a	10.33 a	10.67 a	10.67 a
S_2B_1	2.67 ab	8.67 bc	8.67 cd	8.67 cd	8.67 cd
S_2B_2	3.00 ab	8.33 c	8.33 d	8.33 d	8.33 d
S_2B_3	3.00 ab	8.33 c	9.00 b-d	9.00 b-d	9.00 b-d
S_3B_0	3.00 ab	9.00 abc	9.33 a-d	9.33 a-d	9.33 a-d
S_3B_1	3.00 ab	8.33 c	8.67 cd	8.67 cd	8.67 cd
S_3B_2	3.00 ab	8.67 bc	9.00 b-d	9.00 b-d	9.00 b-d
S_3B_3	2.67 ab	9.00 a-c	9.67 a-c	9.67 a-d	9.67 a-d
$LSD_{(0.05)}$	1.46	1.27	1.27	1.37	1.36
CV (%)	29.3	8.5	8.1	8.7	8.6

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.1.7 Number of secondary branches

4.1.7.1 Effect of sulphur doses

Number of secondary branches was significantly affected by sulphur doses throughout the life cycle (Appendix V and Figure 13). At 60 DAS, maximum number of secondary branches (3.92) was recorded at 37.2 kg ha^{-1} sulphur dose which was statistically similar (3.08) with 27.9 kg ha^{-1} sulphur dose and minimum number of secondary branches (2.67) was observed at 18.6 kg ha^{-1} sulphur dose which was statistically similar with 0 kgha^{-1} and 27.9 kg ha^{-1}

sulphur doses. At 75 DAS and at harvest, maximum number of secondary branches (4.33 and 4.33) was recorded at 37.2 kg ha^{-1} sulphur dose and minimum number of secondary branches (3.33 and 3.33) was observed at 18.6 kg ha^{-1} sulphur dose which was statistically similar with 0 kg ha^{-1} and 27.9 kg ha^{-1} sulphur doses. Kanpara *et al.* (1992) found the opposite result. They observed that the growth character of mustard such as primary and secondary branches plant^{-1} was significantly increased up to 100 kg S ha^{-1}.

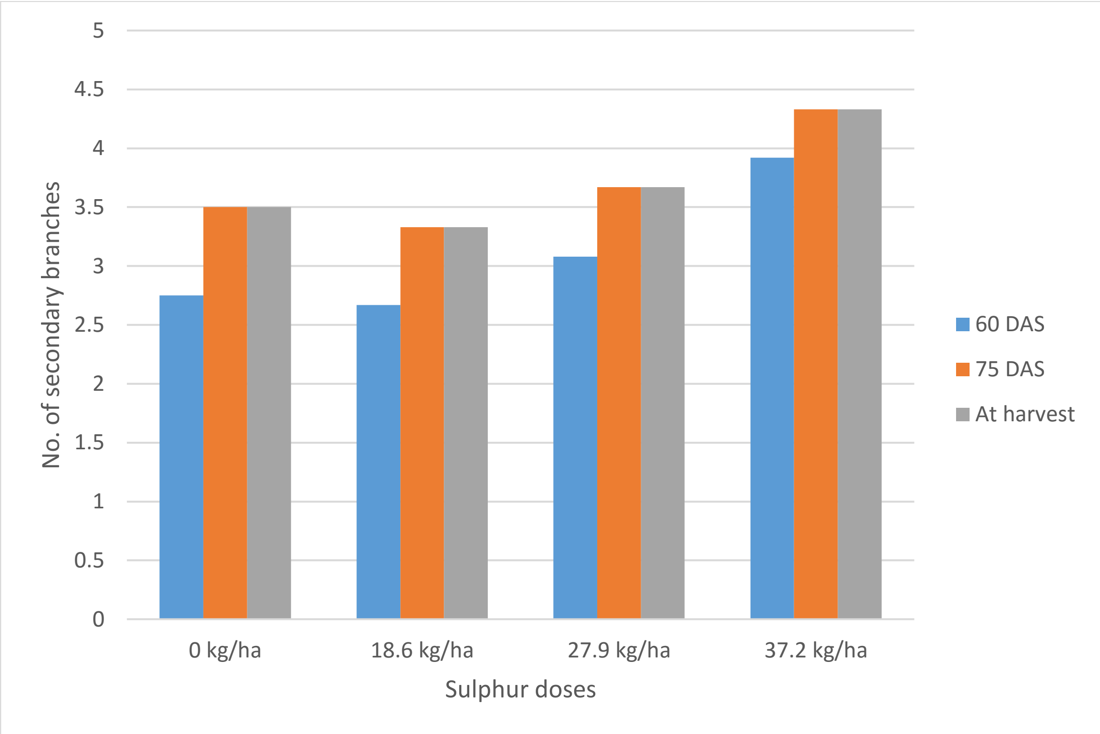

Figure 13. Effect of sulphur doses on secondary branch number of rapeseed plant at different DAS (LSD$_{0.05}$= 1.67, 1.28 and 1.28 at 60 and 75 DAS and at harvest respectively)

4.1.7.2 Effect of boron doses

Number of secondary branches was not significantly affected by boron doses throughout the life cycle (Appendix V and Figure 14). At 60 DAS, maximum number of secondary branches (3.25) was recorded at 0.875 kg ha^{-1} boron dose and minimum number of secondary branches (2.92) was observed at 2.625 kgha^{-1} boron dose. At 75 DAS and at harvest, maximum number of secondary branches (4 and 4) was recorded at 0.875 kg ha^{-1} boron dose and minimum number of secondary branches (3.58 and 3.58) was observed both at with 0 kg ha^{-1} and 2.625 kg ha^{-1} boron doses. All the treatments showed statistically same result throughout the lifecycle.

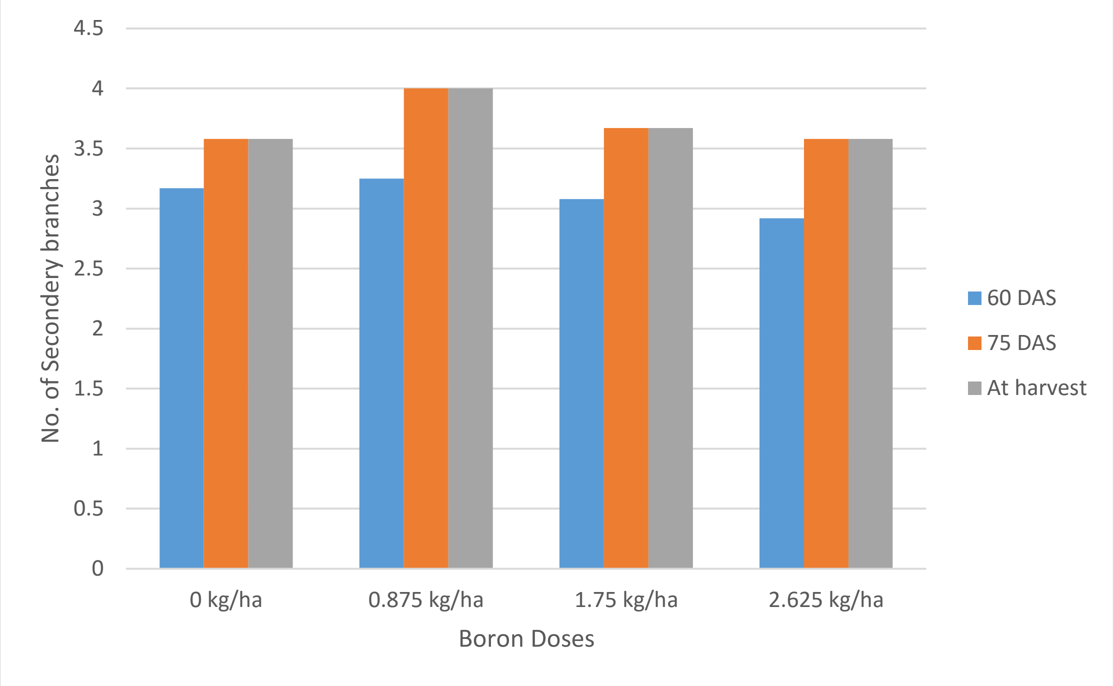

Figure 14. Effect of boron doses on secondary branch number of rapeseed plant at different DAS ($LSD_{0.05}$= 1.67, 1.28 and 1.28 at 60 and 75 DAS and at harvest respectively)

4.1.7.3. Interaction effect of sulphur and boron doses

Number of secondary branches was not significantly affected by the interaction of sulphur and boron doses throughout the lifecycle which is shown in Table 7. At 60 DAS, maximum number of secondary branches (4.67) were recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3) which were statistically similar with S_0B_2, S_1B_0, S_1B_1, S_2B_0, S_2B_1, S_2B_2, S_3B_0, S_3B_1 and S_3B_2. On the other hand, minimum number of secondary branches (2) were observed at the combination of 18.6 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_1B_3) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_2B_0, S_2B_1, S_2B_2, S_2B_3, S_3B_0 and S_3B_2. At 75 DAS and at harvest, maximum number of secondary branches (5 and 5) were recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3) which were statistically similar with S_1B_1, S_2B_1, S_2B_2, S_3B_1 and S_3B_2. On the other hand, minimum number of secondary branches (3 and 3) were observed at the combination of 18.6 kg ha^{-1} sulphur dose & 1.75 kg ha^{-1} boron dose (S_1B_2), 18.6 kgha^{-1} sulphur dose & 2.625 kg ha^{-1} boron dose (S_1B_3) and 27.9 kg ha^{-1} sulphur dose & 2.625 kg ha^{-1} boron dose (S_2B_3) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_2B_0, S_2B_1, S_2B_2, S_3B_0 and S_3B_2.

Table 7. Interaction effect of sulphur and boron doses on secondary branches at 60, 75 DAS and at harvest

Treatments	60 DAS	75 DAS	At harvest
S_0B_0	2.67 bc	3.67 bc	3.67 bc
S_0B_1	2.67 bc	3.33 c	3.33 c
S_0B_2	3.00 a-c	3.67 bc	3.67 bc
S_0B_3	2.67 bc	3.33 c	3.33 c
S_1B_0	3.00 a-c	3.33 c	3.33 c
S_1B_1	3.33 a-c	4.00 a-c	4.00 a-c
S_1B_2	2.33 bc	3.00 c	3.00 c
S_1B_3	2.00 c	3.00 c	3.00 c
S_2B_0	3.33 a-c	3.67 bc	3.67 bc
S_2B_1	3.00 a-c	4.00 a-c	4.00 a-c
S_2B_2	3.67 a-c	4.00 a-c	4.00 a-c
S_2B_3	2.33 bc	3.00 c	3.00 c
S_3B_0	3.67 a-c	3.67 bc	3.67 bc
S_3B_1	4.00 ab	4.67 ab	4.67 ab
S_3B_2	3.33 a-c	4.00 a-c	4.00 a-c
S_3B_3	4.67 a	5.00 a	5.00 a
$LSD_{(0.05)}$	1.67	1.28	1.28
CV (%)	32.3	20.8	20.8

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.2 Yield contributing characters

4.2.1 Number of siliquae plant^{-1}

4.2.1.1 Effect of sulphur doses

Number of siliquae plant^{-1} was significantly affected by sulphur doses (Appendix V and Figure 15). Maximum number of siliquae plant^{-1} (181.42) was recorded at 37.2 kg ha^{-1} sulphur dose and minimum number of siliquae plant^{-1} (151.67) was observed at 0 kg ha^{-1} sulphur dose. Chauhan *et al.* (1996) also observed that each successive increase in S level from 0-50 kg ha^{-1} significantly increased the number of siliqua plant^{-1}.

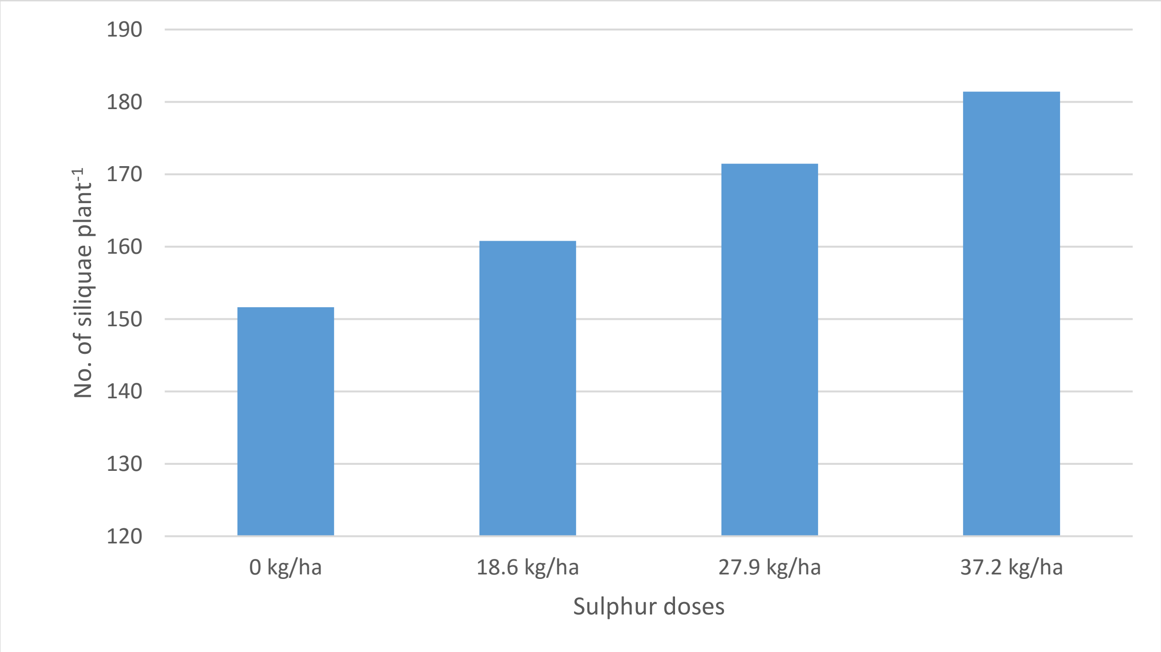

Figure 15. Effect of sulphur doses on number of siliquae plant^{-1} of rapeseed plant ($LSD_{0.05}$= 13.03)

4.2.1.1 Effect of boron doses

Number of siliquae plant^{-1} was significantly affected by boron doses (Appendix V and Figure 16). Maximum number of siliquae plant^{-1} (194.75) was recorded at 2.625 kg ha^{-1} boron dose which was statistically similar (188.92) with the application of 1.75 kg ha^{-1} boron and minimum number of siliquae plant^{-1} (126.67) was observed at 0 kg ha^{-1} boron dose.

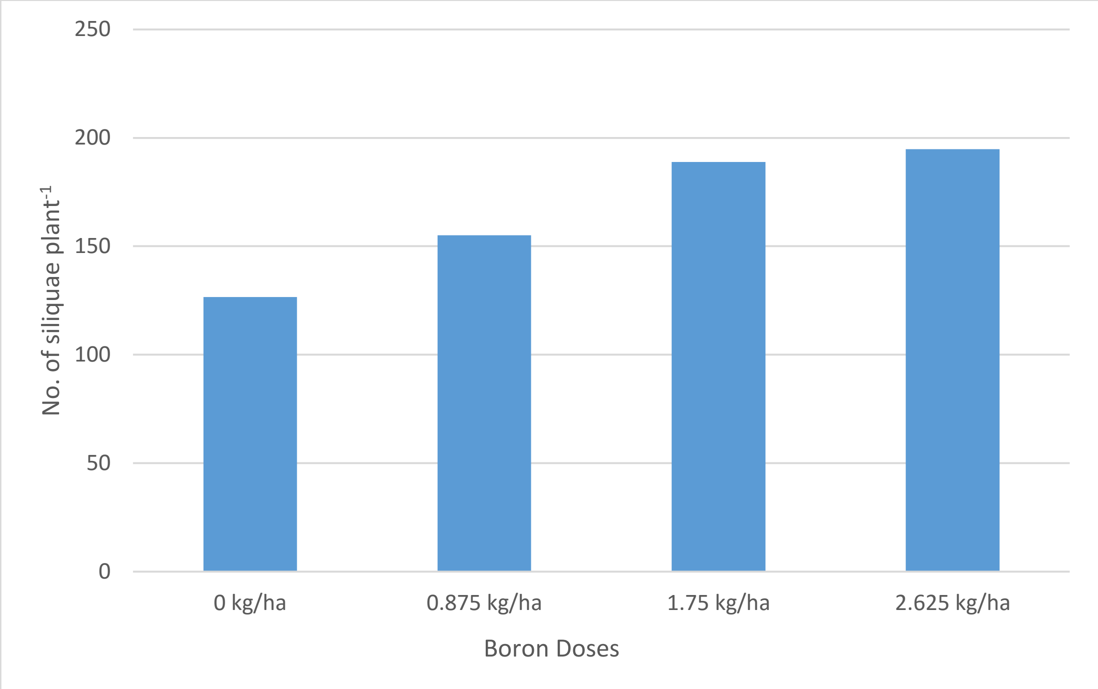

Figure 16. Effect of boron doses on number of siliquae plant^{-1} of rapeseed plant ($LSD_{0.05}$= 13.03)

4.2.1.3. Interaction effect of sulphur and boron doses

Number of siliquae plant^{-1} was not significantly affected by the interaction of sulphur and boron doses which is shown at Table 8. Combination of 37.2 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_3B_3) scored the maximum number of siliquae plant^{-1} (209.67) which was statistically similar (199 and 208.33) with S_2B_3 and S_3B_2. On the other hand, minimum number of siliquae plant^{-1} (112) was recorded at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_0B_0) which was statistically similar (123.67) with S_1B_0.

4.2.2 Sterility

4.2.2.1 Number of sterile siliquae plant^{-1}

4.2.2.1.1 Effect of sulphur doses

Number of sterile siliquae plant^{-1} was not significantly affected by sulphur doses (Appendix V and Figure 17). Maximum number of sterile siliquae plant^{-1} (7.25) was recorded at 27.9 kg ha^{-1} sulphur dose which was statistically similar (6.94 and 6.92) with 18.6 kgha^{-1} and 37.2 kg ha^{-1} sulphur dose. On the other hand, minimum number of sterile siliquae plant^{-1} (6.03) was observed at 0 kg ha^{-1} sulphur dose which was statistically similar with 18.6 kgha^{-1} and 37.2 kg ha^{-1} sulphur dose.

4.2.2.1.2 Effect of boron doses

Number of sterile siliquae plant^{-1} was not significantly affected by boron doses (Appendix V and Figure 18). Maximum number of sterile siliquae plant^{-1} (7.06) was recorded at 0.875 kg ha^{-1} boron dose and minimum number of sterile siliquae plant^{-1} (6.25) was observed at 1.75 kg ha^{-1} boron dose. All the treatments showed statistically same result.

4.2.2.1.3 Interaction effect of sulphur and boron doses

Number of sterile siliquae plant^{-1} was not significantly affected by the interaction of sulphur and boron doses which is shown at Table 8. Combination of 27.9 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_2B_3) scored the maximum number of sterile siliquae plant^{-1} (8) which was statistically similar with S_0B_0, S_0B_1, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_3B_0, S_3B_1, S_3B_2 and S_3B_3. On the other hand, minimum number of sterile siliquae plant^{-1} (5.33) was recorded at the combination of 0 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_0B_2) which was statistically similar with S_0B_0, S_0B_1, S_0B_3, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_1, S_2B_2, S_3B_0, S_3B_2 and S_3B_3.

4.2.2.2 Sterility Percentage

4.2.2.2.1 Effect of sulphur doses

Sterility percentage of siliqua was not significantly affected by sulphur doses (Appendix V and Figure 17). Highest sterility percentage (4.48%) was recorded at 18.6 kg ha^{-1} sulphur doses and lowest sterility percentage (3.92%) was observed at 37.2 kg ha^{-1} sulphur doses. All the treatments showed statistically same result.

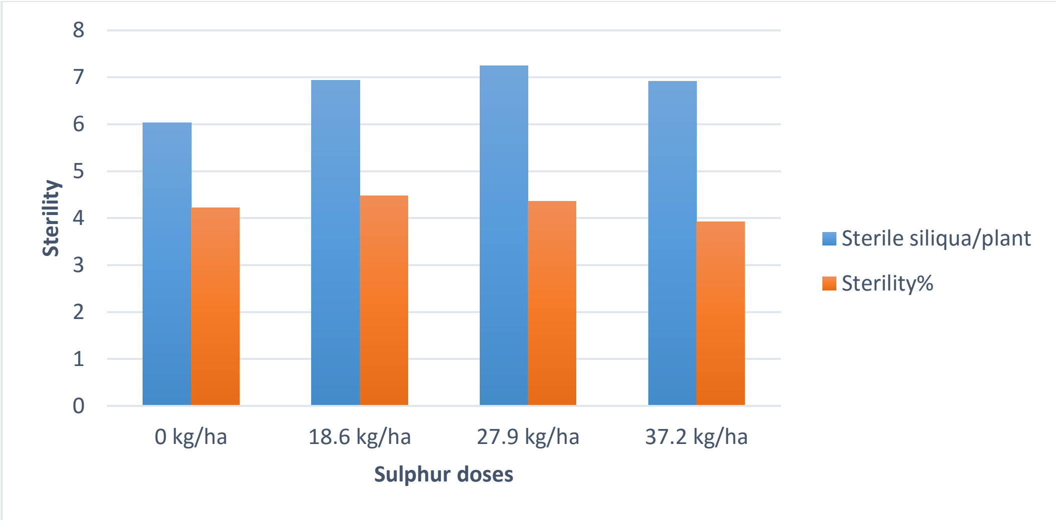

Figure 17. Effect of sulphur doses on sterility of siliqua of rapeseed plant ($LSD_{0.05}$= 2 and 1.15)

4.2.2.2.2 Effect of boron doses

Sterility percentage of siliqua was significantly affected by boron doses (Appendix V and Figure 18). Highest sterility percentage (5.58) was recorded at 0 kg ha^{-1} boron dose and lowest sterility percentage (3.32%) was observed at 1.75 kg ha^{-1} boron dose which was statistically similar (3.51%) with 2.625 kg ha^{-1} boron dose. Zaman *et al.* (1998) also found that *Brassica napus*, the mother of developed genotypes, often shows sterility in many areas of the country. It is suspected that this variety is highly sensitive to boron deficiency.

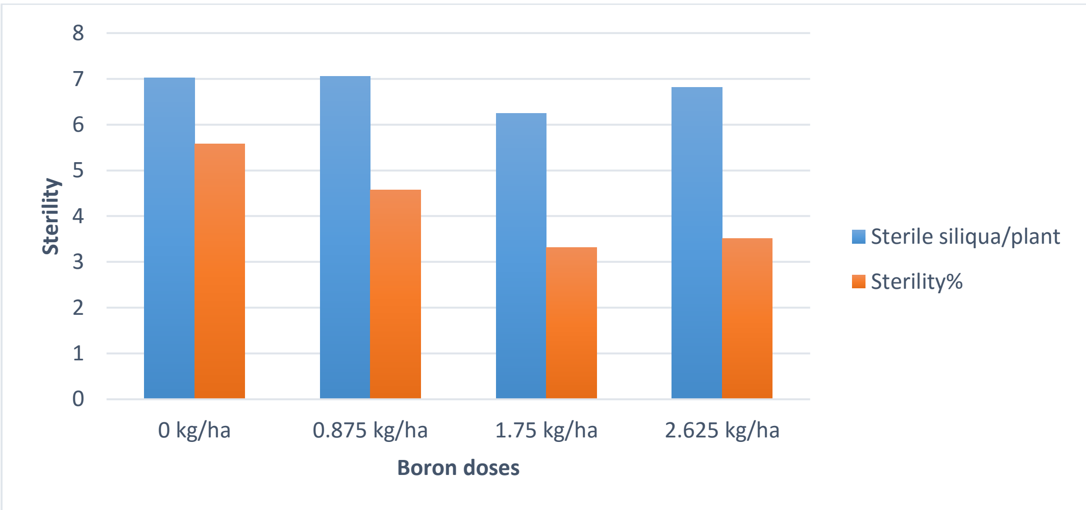

Figure 18. Effect of boron doses on sterility of siliqua of rapeseed plant ($LSD_{0.05}$= 2 and 1.15)

4.2.2.2.3 Interaction effect of sulphur and boron doses

Sterility percentage of siliqua of rapeseed plant was not significantly affected by the interaction of sulphur and boron doses which is shown at Table 8. Highest sterility percentage (6.28%) was recorded at the combination of 18.6 kg ha^{-1} sulphur dose and 0 $kgha^{-1}$ boron dose (S_1B_0) which was statistically similar with S_0B_0 and S_1B_3. Lowest sterility percentage (3.03%) was recorded at the combination of 37.2 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_3B_2) which was statistically similar with S_0B_2, S_0B_3, S_1B_2, S_1B_3, S_2B_1, S_2B_2, S_2B_3 and S_3B_3.

4.2.3 Siliqua length

4.2.3.1 Effect of sulphur doses

Siliqua length (cm) of rapeseed plant was not significantly affected by sulphur doses (Appendix V and Figure 19). Biggest siliqua length (5.05 cm) was recorded at 0 kg ha^{-1} sulphur dose which was statistically similar (5.01 and 5 cm) with the application of 18.6 kg ha^{-1} and 27.9 kg ha^{-1} sulphur doses. On the other hand, smallest siliqua length (4.89 cm) was observed at 37.2 kg ha^{-1} sulphur dose which was statistically similar with 18.6 kg ha^{-1} and 27.9 kg ha^{-1} sulphur doses.

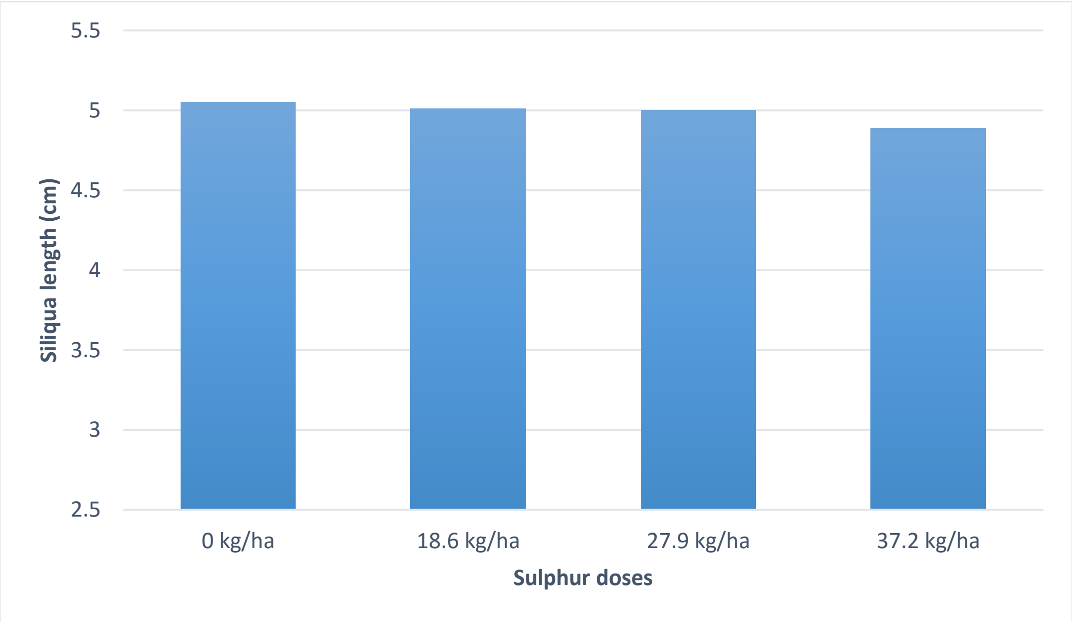

Figure 19. Effect of sulphur doses on siliqua length (cm) of rapeseed plant ($LSD_{0.05}$= 0.27)

4.2.3.2 Effect of boron doses

Siliqua length (cm) of rapeseed plant was significantly affected by boron doses (Appendix V and Figure 20). Biggest siliqua length (5.16 cm) was recorded at 0 kg ha^{-1} boron dose and smallest siliqua length (4.89 cm) was observed at 2.625 kg ha^{-1} boron dose which was statistically similar with 0.875 kg ha^{-1} and 2.625 kg ha^{-1} boron doses.

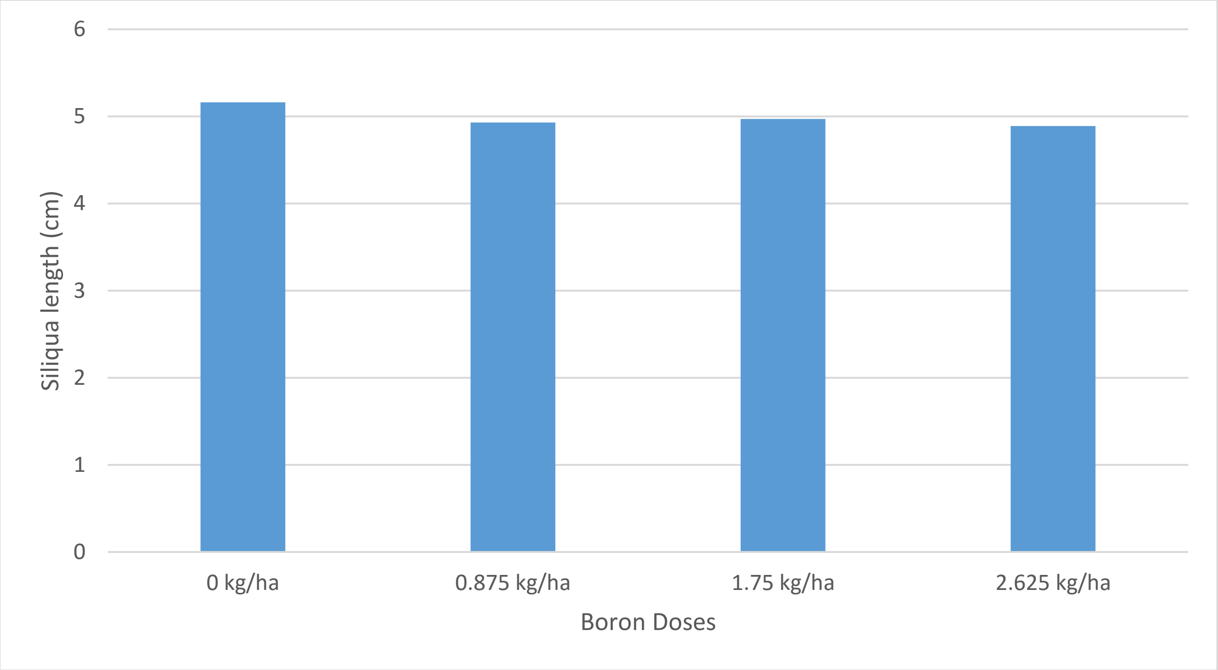

Figure 20. Effect of boron doses on siliqua length (cm) of rapeseed plant ($LSD_{0.05}$= 0.27)

4.2.3.3 Interaction effect of sulphur and boron doses

Siliqua length (cm) was not significantly affected by the interaction of sulphur and boron doses which is shown at Table 6. Biggest siliqua length (5.33 cm) was recorded at the combination of 27.9 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_2B_0) which was statistically similar with S_0B_0, S_0B_1 and S_1B_0. On the other hand smallest siliqua length (4.74 cm) was observed at the combination of 27.9 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_2B_1) which was statistically similar with S_0B_3, S_1B_1, S_1B_2, S_1B_3, S_2B_2, S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3.

4.2.4 Number of seeds siliqua^{-1}

4.2.4.1 Effect of sulphur doses

Number of seeds siliqua^{-1} of rapeseed plant was not significantly affected by sulphur doses (Appendix V and Figure 21). Maximum number of seeds siliqua^{-1} (23.06) was recorded at 0 kg ha^{-1} sulphur dose which was statistically similar (22.45 and 21.57) with the application of 18.6 kgha^{-1} and 27.9 kg ha^{-1} sulphur doses. On the other hand, minimum number of seeds siliqua^{-1} (21.4) was observed at 37.2 kg ha^{-1} sulphur dose which was statistically similar with 18.6 kg ha^{-1} and 27.9 kg ha^{-1} sulphur doses. But Rahman *et al.* (1978) reported that the application of sulphur was favourable for the production of more seeds siliqua^{-1}.

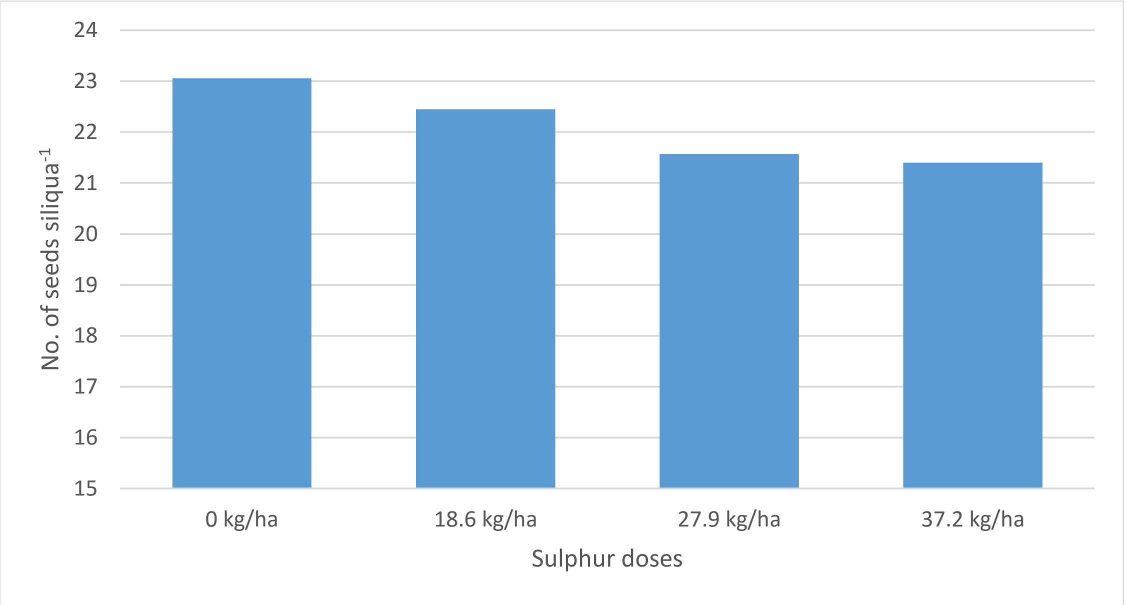

Figure 21: Effect of sulphur doses on number of seeds siliqua^{-1} of rapeseed plant ($LSD_{0.05}$= 3.07)

4.2.4.1 Effect of boron doses

Number of seeds siliqua^{-1} of rapeseed plant was not significantly affected by boron doses (Appendix V and Figure 22). Maximum number of seeds siliqua^{-1} (22.86) was recorded at 2.625 kg ha^{-1} boron dose and minimum number of seeds siliqua^{-1} (21.63) was observed at 1.75 kg ha^{-1} boron dose. All the treatments showed statistically same result.

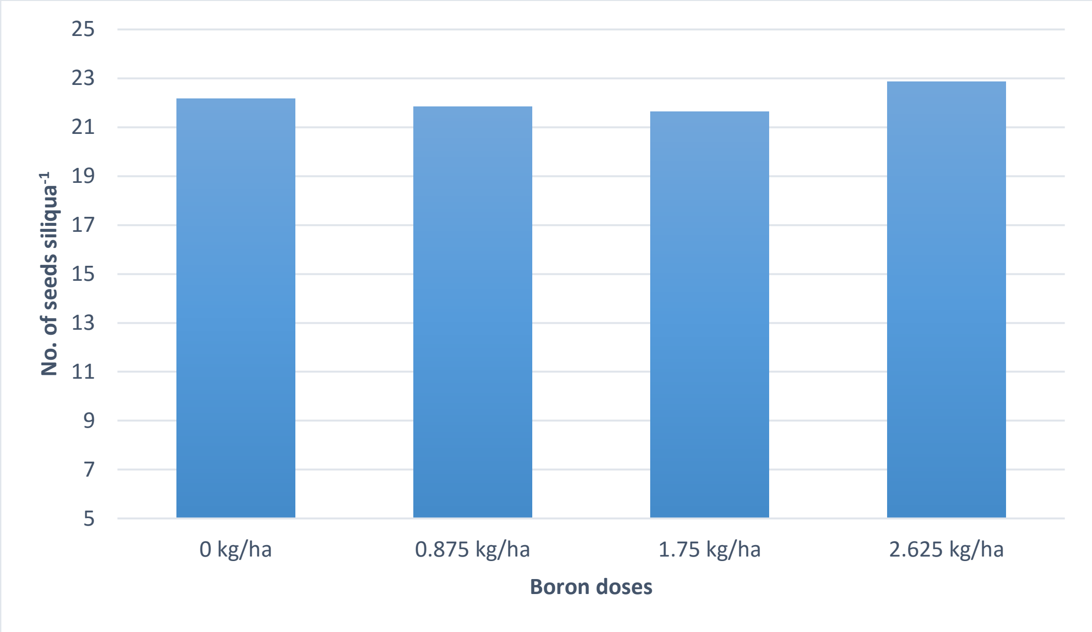

Figure 22. Effect of boron doses on number of seeds siliqua^{-1} of rapeseed plant ($LSD_{0.05}$= 3.07)

4.2.4.3 Interaction effect of sulphur and boron doses

Number of seeds siliqua^{-1} was significantly affected by the interaction of sulphur and boron doses which is shown at Table 8. Maximum number of seeds siliqua^{-1} (25.2) was recorded at the combination of 18.6 kg ha^{-1} sulphur dose and 2.625 kg ha^{-1} boron dose (S_1B_3) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_1, S_2B_0 and S_2B_3. Minimum number of seeds siliqua^{-1} (19.43) was observed at the combination of 27.9 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_2B_2) which was statistically similar with S_0B_1, S_1B_0, S_1B_2, S_2B_1. S_2B_3, S_3B_0, S_3B_1, S_3B_2 and S_3B_3.

Table 8. Interaction effect of sulphur and boron doses on siliqua plant^{-1}, sterile siliqua plant^{-1}, %sterility, siliqua length and seed siliqua^{-1}

Treatments	No. of siliquae plant^{-1}	No. of sterile siliquae plant^{-1}	Sterility (%)	Siliqua length (cm)	No. of seeds siliqua^{-1}
S_0B_0	112.00 i	6.33 a-c	5.63 ab	5.23 ab	22.87 a-d
S_0B_1	134.67 gh	6.56 a-c	4.89 bc	5.08 a-d	22.5 a-e
S_0B_2	178.00 cd	5.33 c	3.05 f	5.01 b-e	23.67 a-c
S_0B_3	182.00 c	5.89 bc	3.31 f	4.88 de	23.20 a-d
S_1B_0	123.67 hi	7.78 ab	6.28 a	5.22 a-c	20.17 de
S_1B_1	153.33 ef	7.33 a-c	4.77 b-d	4.95 c-e	23.13 a-d
S_1B_2	178.00 c	6.33 a-c	3.53 ef	4.93 de	21.30 b-e
S_1B_3	188.00 bc	6.33 a-c	3.34 f	4.93 de	25.20 a
S_2B_0	130.00 gh	7.33 a-c	5.69 ab	5.33 a	24.07 ab
S_2B_1	165.67 de	6.67 a-c	4.02 c-f	4.74 e	20.63 c-e
S_2B_2	191.33 bc	7.00 a-c	3.68 d-f	5.01 b-e	19.43 e
S_2B_3	199.00 ab	8.00 a	4.04 c-f	4.91 de	22.13 a-e
S_3B_0	141.00 fg	6.67 a-c	4.73 b-d	4.85 de	21.57 b-e
S_3B_1	166.67 d	7.67 ab	4.58 b-e	4.93 de	21.03 b-e
S_3B_2	208.33 a	6.33 a-c	3.03 f	4.93 de	22.10 b-e
S_3B_3	209.67 a	7.00 a-c	3.36 f	4.83 de	20.90 c-e
$LSD_{(0.05)}$	13.03	2	1.15	0.27	3.07
CV (%)	4.7	17.7	16.3	3.2	8.3

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.2.5 Siliquae shell Yield

4.2.5.1 Effect of sulphur doses

Silique shell yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of sulphur (Appendix V and Figure 23). Highest shell yield (1.64 t ha^{-1}) was obtained at 27.9 kg ha^{-1} which was statistically similar (1.62 t ha^{-1})

with the application of 37.2 kg ha^{-1} sulphur dose. Lowest shell yield (1.01 t ha^{-1}) was found at 0 kg ha^{-1} sulphur dose.

4.2.5.2 Effect of boron doses

Shell yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of boron (Appendix V and Figure 24). Highest shell yield (1.48 t ha^{-1}) was obtained at 1.75 kg ha^{-1} which was statistically similar (1.46 t ha^{-1}) with the application of 2.625 kg ha^{-1} boron dose. Lowest shell yield (1.27 t ha^{-1}) was found at 0 kgha^{-1} boron dose.

4.2.5.3 Interaction effect of sulphur and boron doses

Shell yield (t ha^{-1}) was not significantly affected by the interaction of sulphur and boron doses which was shown at Table 9. Highest shell yield (1.73 t ha^{-1}) was obtained at the combination of 27.9 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_2B_2) which was statistically similar with S_2B_3, S_3B_2 and S_3B_3. Lowest shell yield (0.87 t ha^{-1}) was found at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_0B_0).

4.2.6 Stover Yield

4.2.6.1 Effect of sulphur doses

Stover yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of sulphur (Appendix V and Figure 23). Highest stover yield (4.03 t ha^{-1}) was obtained at 37.2 kg ha^{-1} sulphur dose and lowest stover yield (2.89 t ha^{-1}) was found at 0 kg ha^{-1} sulphur dose. Jaggi and Sharma (1997) also reported that application of S progressively increased the seed and stover yields. However, the effect was significant up to 60 kg S ha^{-1} in seed and 90 kg S ha^{-1} in stover yield.

4.2.6.2 Effect of boron doses

Stover yield (t ha^{-1}) of rapeseed plant was not significantly affected by different doses of boron (Appendix V and Figure 24). Highest stover yield (3.6 t ha^{-1}) was obtained at 2.625 kg ha^{-1} boron dose which was statistically similar (3.55 and 3.58 t ha^{-1}) with the application of 0.875 kg ha^{-1} and 1.75 kg ha^{-1} boron dose.

Lowest stover yield (3.53 t ha^{-1}) was found at 0 kg ha^{-1} boron dose which was statistically similar with the doses 0.875 kg ha^{-1} and 1.75 kg ha^{-1}.

4.2.6.3 Interaction effect of sulphur and boron doses

Stover yield (t ha^{-1}) was not significantly affected by the interaction of sulphur and boron doses which was shown at Table 9. Highest stover yield (4.04 t ha^{-1}) was obtained both at the combination of 37.2 kg ha^{-1} sulphur dose & 0.875 kg ha^{-1} boron dose (S_3B_1) and 37.2 kg ha^{-1} sulphur dose & 2.625 kg ha^{-1} boron dose (S_3B_3) which were statistically similar with S_2B_3, S_3B_0 and S_3B_2. Lowest stover yield (2.85 t ha^{-1}) was found at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_0B_0) which was statistically similar with S_0B_1, S_0B_2 and S_0B_3.

4.2.7 Grain yield

4.2.7.1 Effect of sulphur doses

Grain yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of sulphur (Appendix V and Figure 23). Highest grain yield (2.96 t ha^{-1}) was obtained at 27.9 kg ha^{-1} which was statistically similar (2.93 t ha^{-1}) with the application of 37.2 kg ha^{-1} sulphur dose. Lowest grain yield (2.17 t ha^{-1}) was found at 0 kg ha^{-1} sulphur dose. Singh *et al.* (1970) also reported that S requirement of oil crops was found to be high. The yield of mustard was increased due to application of S particularly in the form of gypsum.

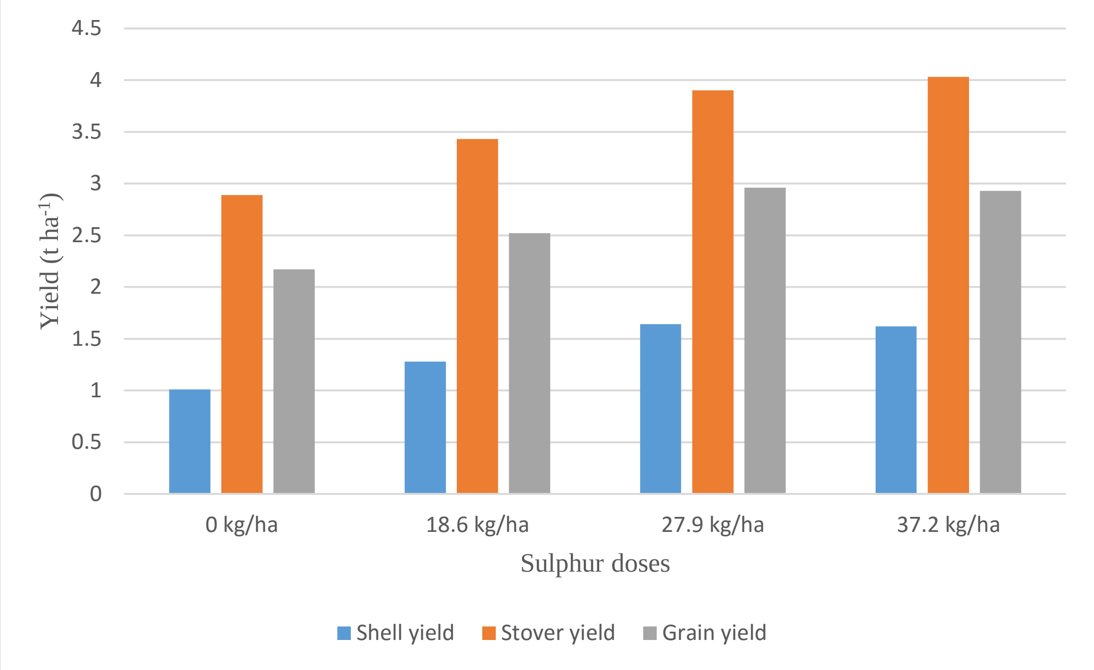

Figure 23. Effect of sulphur doses on yield of rapeseed plant ($LSD_{0.05}$= 0.065, 0.011 and 0.011)

4.2.7.2 Effect of boron doses

Grain yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of boron (Appendix V and Figure 24). Highest grain yield (2.73 t ha^{-1}) was obtained at 1.75 kg ha^{-1} which was statistically similar (2.71 t ha^{-1}) with the application of 2.625 kg ha^{-1} boron dose. Lowest grain yield (2.53 t ha^{-1}) was found at 0 kg ha^{-1} boron dose. Direct effects of boron are reflected by the close relationship between boron supply and pollen producing capacity of the anthers as well as the viability of the pollen grains (Agarwala *et al.*, 1981). Moreover, boron stimulates pollen germination, particularly pollen tube growth. Boron is also essential for sugar translocation, thus affecting carbon and nitrogen metabolism of plants (Jackson and Champman, 1975). Thus it affects the seed formation and development and consequently the yield of crops.

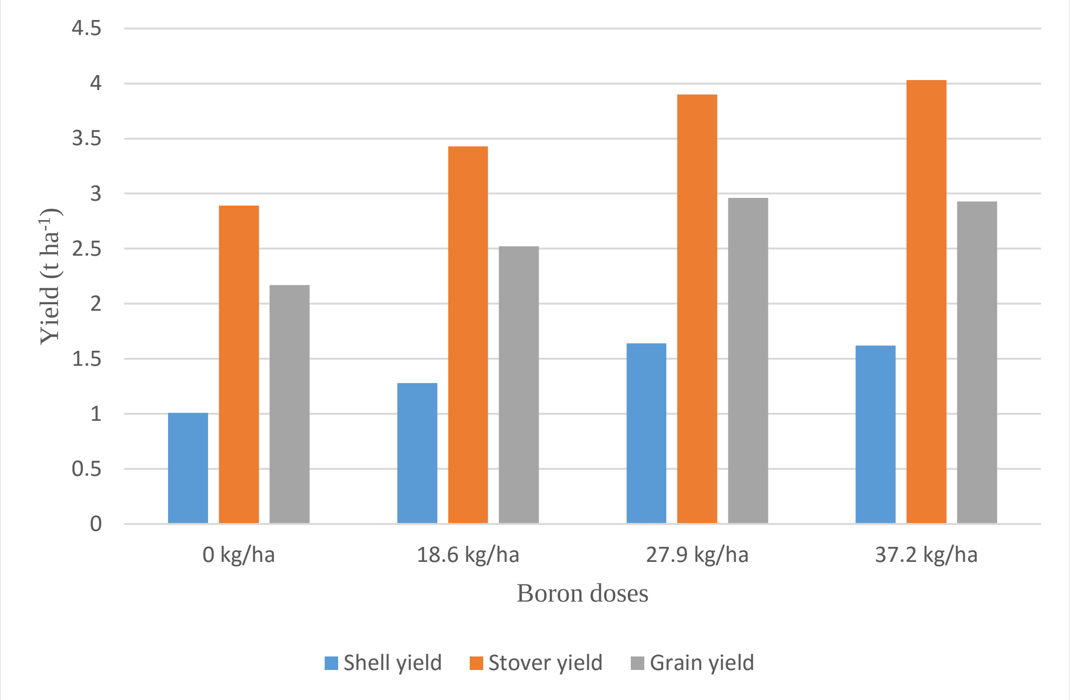

Figure 24: Effect of boron doses on yield of rapeseed plant ($LSD_{0.05}$= 0.065, 0.011 and 0.011)

4.2.7.3 Interaction effect of sulphur and boron doses

Grain yield (t ha^{-1}) was not significantly affected by the interaction of sulphur and boron doses which was shown at Table 9. Highest grain yield (3.07 t ha^{-1}) was obtained at the combination of 27.9 kg ha^{-1} sulphur dose & 1.75 kg ha^{-1} boron dose (S_2B_2) which was statistically similar with S_2B_3, S_3B_2 and S_3B_3. Lowest grain yield (2.1 t ha^{-1}) was found at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_0B_0) which was statistically similar with S_0B_1 and S_0B_3.

4.2.8 Biological yield

4.2.8.1 Effect of sulphur doses

Biological yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of sulphur (Appendix V and Figure 25). Highest biological yield (8.58 t ha^{-1}) was obtained at 37.2 kg ha^{-1} which was statistically similar (8.51 t ha^{-1}) with the application of 27.9 kg ha^{-1} sulphur dose. Lowest biological yield (6.08 t ha^{-1}) was found at 0 kg ha^{-1} sulphur dose.

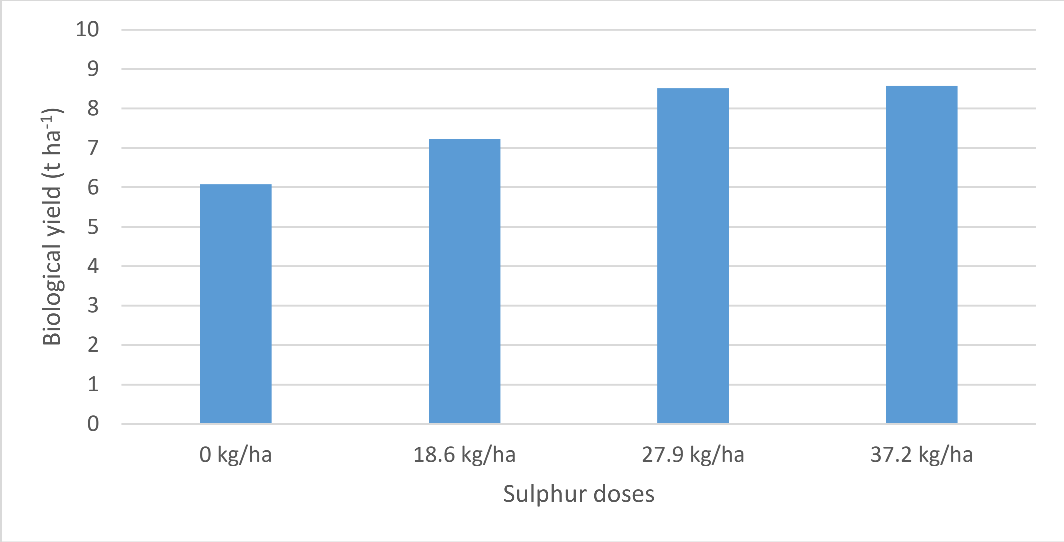

Figure 25. Effect of sulphur doses on biological yield of rapeseed plant ($LSD_{0.05}$= 0.17)

4.2.8.2 Effect of boron doses

Biological yield (t ha^{-1}) of rapeseed plant was significantly affected by different doses of boron (Appendix V and Figure 26). Highest biological yield (7.79 t ha^{-1}) was obtained at 1.75 kg ha^{-1} which was statistically similar (7.76 t ha^{-1}) with the application of 2.625 kg ha^{-1} boron dose. Lowest biological yield (7.33 t ha^{-1}) was found at 0 kg ha^{-1} boron dose.

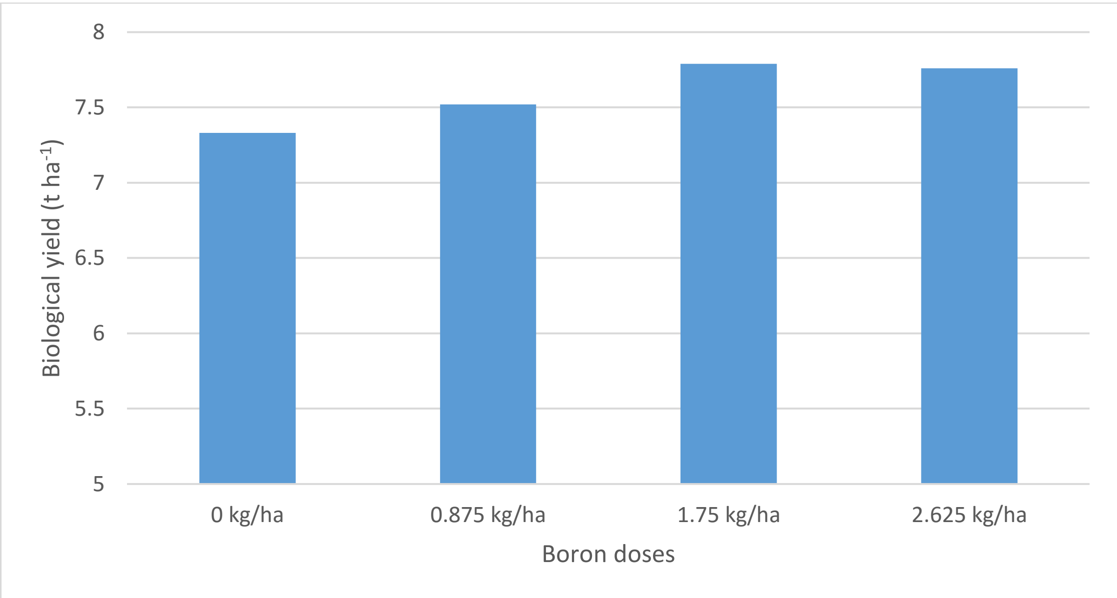

Figure 26. Effect of boron doses on biological yield of rapeseed plant ($LSD_{0.05}$= 0.17)

4.2.8.3 Interaction effect of sulphur and boron doses

Biological yield (t ha^{-1}) was not significantly affected by the interaction of sulphur and boron doses which was shown at Table 9. Highest biological yield (8.76 t ha^{-1}) was obtained at the combination of 37.2 kg ha^{-1} sulphur dose & 1.75 kg ha^{-1} boron dose (S_3B_2) which was statistically similar with S_2B_2, S_2B_3 and S_3B_3. Lowest biological yield (5.83 t ha^{-1}) was found at the combination of 0 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_0B_0) which was statistically similar (6.01) with S_0B_1.

4.2.9 Harvest index

4.2.9.1 Effect of sulphur doses

Harvest Index (%) of rapeseed plant was significantly affected by different doses of sulphur application (Appendix V and Figure 27). Highest harvest index (35.73%) was observed at 0 kg ha^{-1} sulphur dose and lowest harvest index (34.1%) was obtained at 37.2 kg ha^{-1} sulphur application.

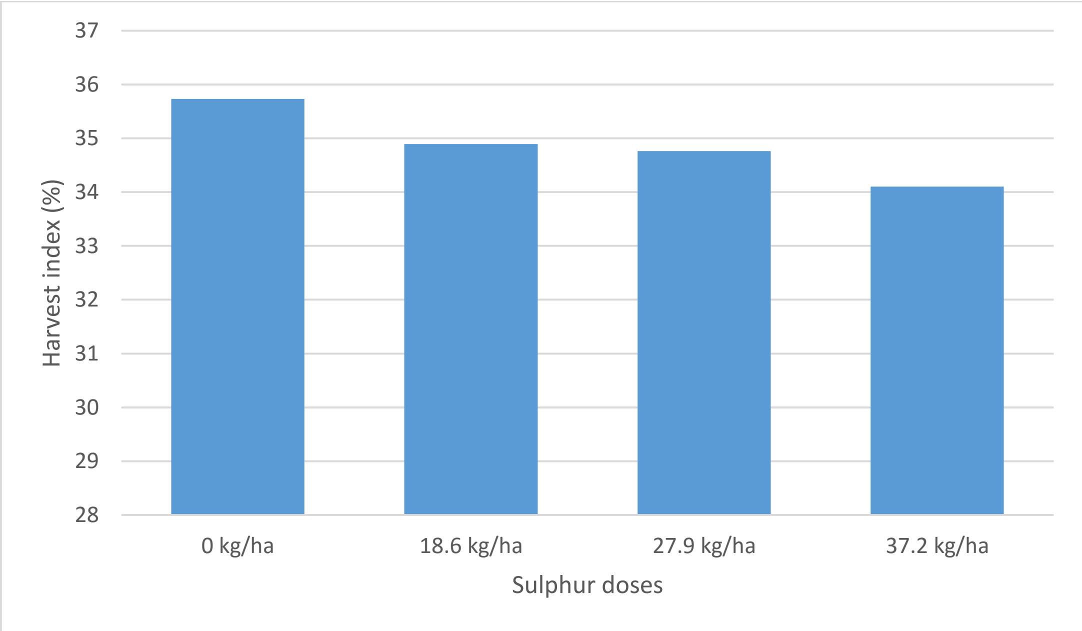

Figure 27. Effect of sulphur doses on harvest index of rapeseed plant ($LSD_{0.05}$= 1.02)

4.2.9.2 Effect of boron doses

Harvest Index of rapeseed plant was not significantly affected by different doses of boron application (Appendix V and Figure 28). Highest harvest index (35.08%) was observed at 1.75 kg ha^{-1} sulphur dose and lowest harvest index (34.6%) was obtained at 0 kg ha^{-1} sulphur application. All the treatments showed statistically same result.

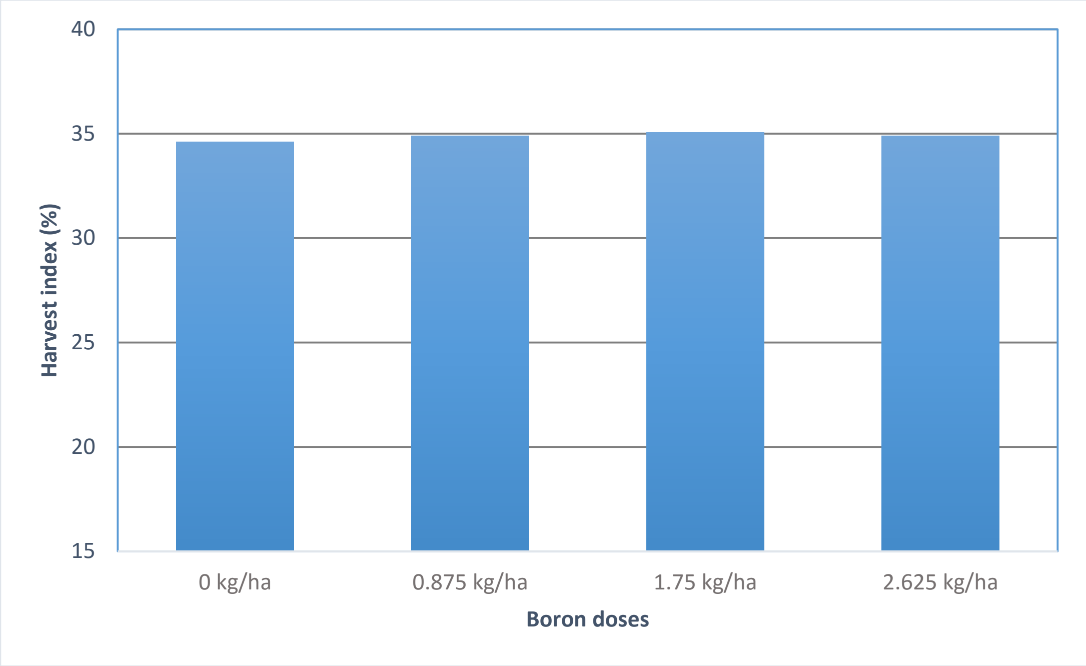

Figure 28. Effect of boron doses on harvest index of rapeseed plant ($LSD_{0.05}$= 1.02)

4.2.9.3 Interaction effect of sulphur and boron doses

Harvest Index was not significantly affected by the interaction of sulphur and boron doses which was shown at Table 9. Highest harvest (36.07%) was obtained at the combination of 0 kg ha^{-1} sulphur dose & 0 kg ha^{-1} boron dose (S_0B_0) which was statistically similar with S_0B_1, S_0B_2, S_0B_3, S_1B_2 and S_1B_3. Lowest harvest index (33.55%) was found at the combination of 37.2 kg ha^{-1} sulphur dose and 0 kg ha^{-1} boron dose (S_3B_0) which was statistically similar with S_2B_0, S_3B_1, S_3B_2 and S_3B_3.

Table 9. Interaction effect of sulphur and boron doses on yield and harvest index of rapeseed plant

Treatments	Shell yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest Index (%)
S_0B_0	0.87 j	2.85 g	2.10 h	5.83 i	36.07 a
S_0B_1	0.97 i	2.89 g	2.15 gh	6.01 i	35.81 ab
S_0B_2	1.12 gh	2.89 g	2.22 g	6.23 h	35.62 a-c
S_0B_3	1.10 h	2.93 g	2.21 gh	6.24 h	35.43 a-d
S_1B_0	1.17 g	3.35 f	2.40 f	6.92 g	34.68 c-g
S_1B_1	1.24 f	3.41 ef	2.48 f	7.14 f	34.72 c-g
S_1B_2	1.36 e	3.49 e	2.62 e	7.46 e	35.05 a-g
S_1B_3	1.33 e	3.47 e	2.60 e	7.40 e	35.11 a-f
S_2B_0	1.53 cd	3.90 cd	2.82 cd	8.25 d	34.1 f-h
S_2B_1	1.61 b	3.84 d	2.94 b	8.39 cd	34.99 b-g
S_2B_2	1.73 a	3.92 b-d	3.07 a	8.72 a	35.18 a-e
S_2B_3	1.71 a	3.95 a-d	3.02 ab	8.68 ab	34.78 c-g
S_3B_0	1.51 d	4.01 a-c	2.79 d	8.31 d	33.55 h
S_3B_1	1.58 bc	4.04 a	2.91 bc	8.53 bc	34.03 gh
S_3B_2	1.70 a	4.03 ab	3.02 ab	8.76 a	34.48 d-h
S_3B_3	1.69 a	4.04 a	3.00 ab	8.73 a	34.34 e-h
$LSD_{(0.05)}$	0.07	0.11	0.11	0.17	1.02
CV(%)	2.8	1.9	2.4	1.3	1.7

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

4.2.10 Thousand seed weight

4.2.10.1 Effect of sulphur doses

Thousand seed weight (g) was not significantly affected by different doses of sulphur (Appendix V and Figure 29). Highest weight thousand seeds (3.28 g) were obtained at 27.9 kg ha^{-1} sulphur dose which was statistically similar (3.16 and 3.03 g) with 0 kg ha^{-1} and 37.2 kg ha^{-1} sulphur doses. Lowest weight of thousand seeds (3.02 g) were recorded at 18.6 kg ha^{-1} sulphur dose which was statistically similar with 0 kg ha^{-1} and 37.2 kg ha^{-1} sulphur doses. But Saran and Giri (1990) observed that 1000-seed weight were increased significantly with 60 kg S ha^{-1}.

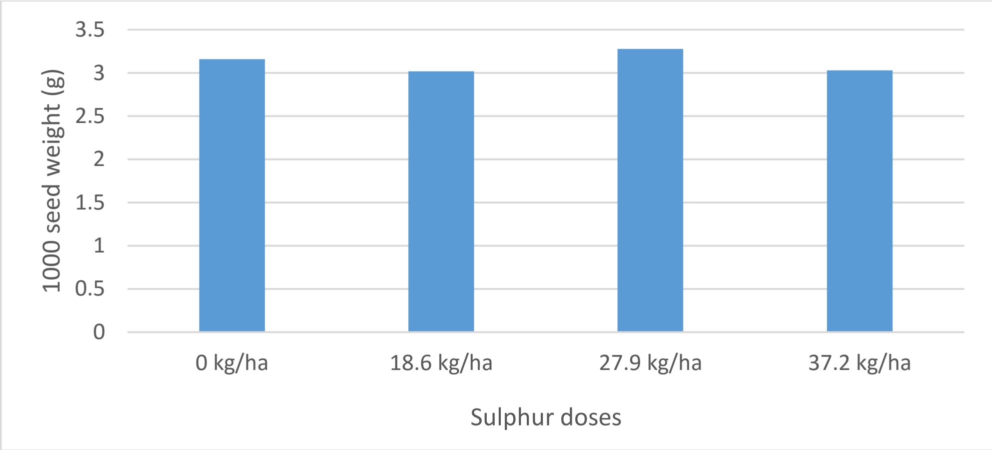

Figure 29. Effect of sulphur doses on thousand seed weight of rapeseed plant (LSD$_{0.05}$= 0.49)

4.2.10.1 Effect of boron doses

Thousand seed weight (g) was not significantly affected by different doses of boron (Appendix V and Figure 30). Highest weight thousand seeds (3.19 g) were obtained at 1.75 kg ha^{-1} boron dose and lowest weight of thousand seeds (3.03 g) were recorded at 2.625 kg ha^{-1} boron dose.

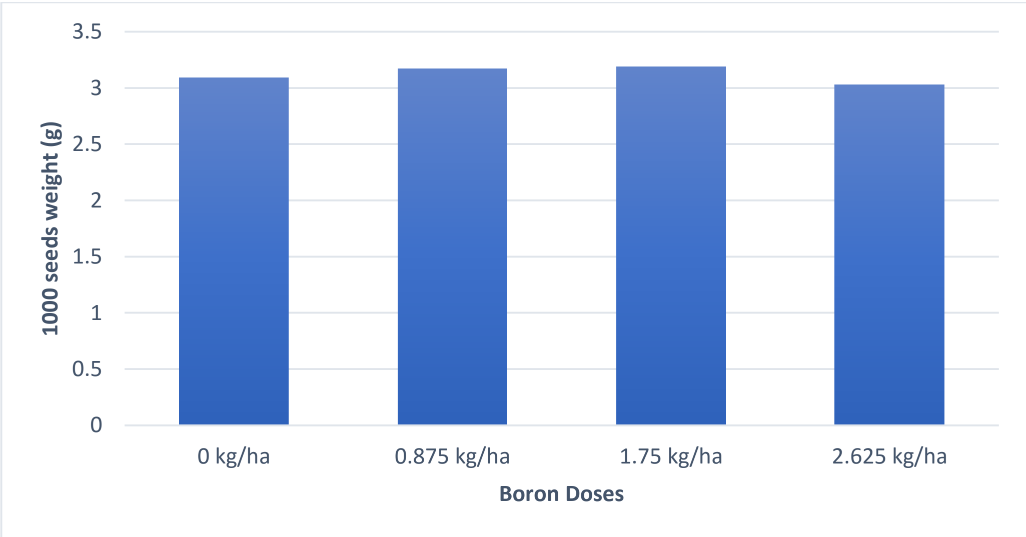

Figure 30. Effect of boron doses on thousand seed weight of rapeseed plant (LSD$_{0.05}$= 0.49)

4.2.10.3 Interaction effect of sulphur and boron doses

Thousand seed weight (g) of rapeseed plant was significantly affected by the interaction of sulphur and boron doses which was shown at Table 10. Highest weight of thousand seed was obtained at the combination of 27.9 kg ha^{-1} sulphur dose and 0.875 kg ha^{-1} boron dose (S_2B_1) which was statistically similar (3.42 g) with S_3B_2. Lowest weight of thousand seed (2.81 g) of rapeseed plant was found at the combination of 37.2 kg ha^{-1} sulphur dos and 0.875 kg ha^{-1} boron dose (S_3B_1) which was statistically similar with S_0B_0, S_0B_1, S_0B_2, S_0B_3, S_1B_0, S_1B_1, S_1B_2, S_1B_3, S_2B_0, S_2B_2, S_2B_3, S_3B_0 and S_3B_3.

4.2.11 Oil Percentage

4.2.11.1 Effect of sulphur doses

Oil percentage of rapeseed plant seed was significantly affected by different doses of sulphur (Appendix V and Figure 31). Highest oil percentage (41.19%) was obtained at 37.2 kg ha^{-1} sulphur and lowest oil percentage (39.52%) was recorded at 0 kg ha^{-1} sulphur dose. Yaduvanshi *et al.* (1980) also observed that an application of 200 kg gypsum ha^{-1} with NPK provided the highest oil content from 34.7% in control to 43.7% in S treatment.

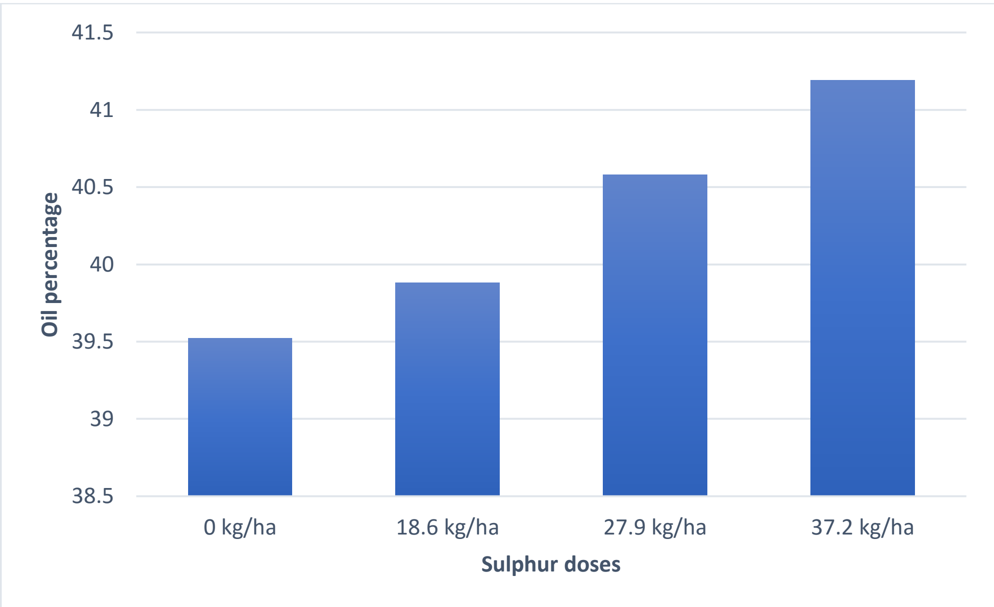

Figure 31. Effect of sulphur doses on oil percentage of rapeseed plant ($LSD_{0.05}$= 0.5)

4.2.11.2 Effect of boron doses

Oil percentage of rapeseed plant seed was not significantly affected by different doses of boron (Appendix V and Figure 32). Highest oil percentage (40.42%) was obtained at 1.75 kg ha^{-1} boron dose and lowest oil percentage (40.17%) was recorded at 0 kg ha^{-1} boron dose. All the treatments showed statistically same result.

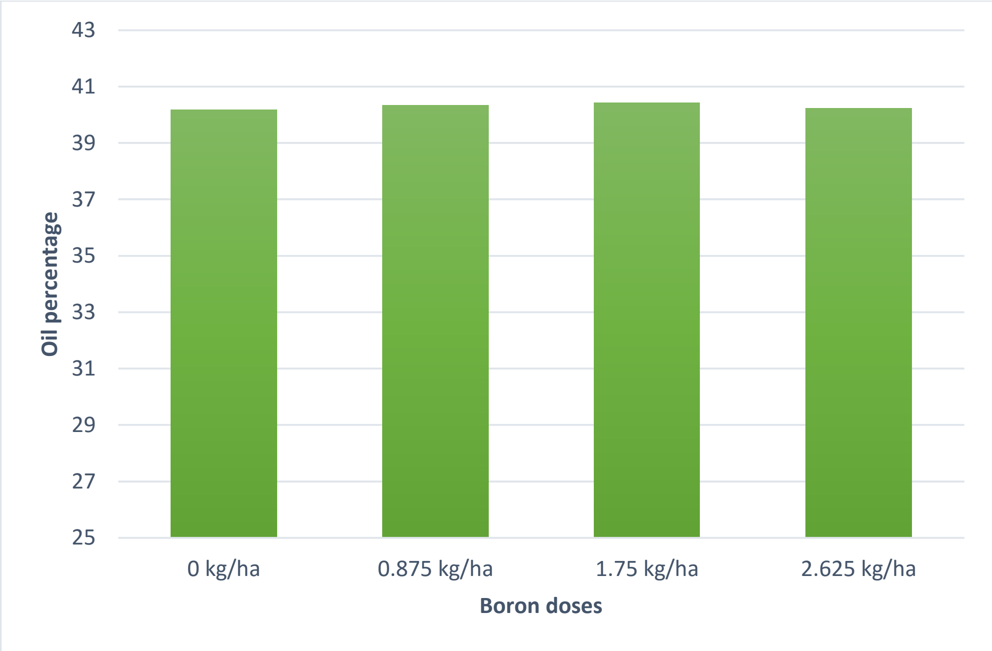

Figure 32. Effect of boron doses on oil percentage of rapeseed plant ($LSD_{0.05}$= 0.5)

4.2.11.3 Interaction effect of sulphur and boron doses

Oil percentage of rapeseed plant seed was not significantly affected by the interaction of sulphur and boron doses which is shown at Table 10. Highest oil percentage (41.32%) was obtained at the combination of 37.2 kg ha^{-1} sulphur dose and 1.75 kg ha^{-1} boron dose (S_3B_2) which was statistically similar with S_3B_0, S_3B_1 and S_3B_3. Lowest oil percentage (39.41%) of rapeseed plant was found at the combination of 0 kg ha^{-1} sulphur dos and 0.875 kg ha^{-1} boron dose (S_0B_1) which was statistically similar with S_0B_0, S_0B_2, S_0B_3, S_1B_0 and S_1B_3.

Table10. Interaction effect of sulphur and boron doses on thousand seed weight and oil percentage of rapeseed plant

Treatments	Thousand seed weight (g)	Oil percentage
S_0B_0	3.13 bc	39.62 gh
S_0B_1	3.12 bc	39.41 h
S_0B_2	3.21 bc	39.62 gh
S_0B_3	3.17 bc	39.42 h
S_1B_0	3.06 bc	39.78 f-h
S_1B_1	2.93 bc	39.94 fg
S_1B_2	3.04 bc	39.93 fg
S_1B_3	3.03 bc	39.88 f-h
S_2B_0	3.09 bc	40.17 ef
S_2B_1	3.83 a	40.72 cd
S_2B_2	3.10 bc	40.8 b-d
S_2B_3	3.08 bc	40.63 c-e
S_3B_0	3.06 bc	41.11 a-c
S_3B_1	2.81 c	41.29 ab
S_3B_2	3.42 ab	41.32 a
S_3B_3	2.85 c	41.04 a-c
$LSD_{(0.05)}$	0.49	0.5
CV(%)	9.5	0.8

S_0= 0 kg ha^{-1} S, S_1= 18.6 kg ha^{-1} S, S_2= 27.9 kg ha^{-1} S, S_3= 37.2 kg ha^{-1} S, B_0= 0 kg ha^{-1} B, B_1= 0.875 kg ha^{-1} B, B_2= 1.75 kg ha^{-1} B, B_3= 2.625 kg ha^{-1} B

Chapter 5

Summary and conclusion

SUMMARY AND CONCLUSION

The present work was done at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from Robi, 2013-14 to to investigate the growth and yield performance of rapeseed as affected by sulphur and boron.

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The size of unit plot was 3 m x 3 m and total number of plot was 48. There were 16 treatments (4 Sulphur doses x 4 Boron doses). The sulphur treatments were 0 kg ha^{-1} (S_0), 18.6 kg ha^{-1} (S_1), 27.9 kg ha^{-1} (S_2) and 37.2 kg ha^{-1} (S_3). Boron treatments were 0 kg ha^{-1} (B_0), 0.875 kg ha^{-1} (B_1), 1.75 kg ha^{-1} (B_2) and 2.625 kg ha^{-1} (B_3).

The data on crop growth parameters like plant height, Number of leaves $plant^{-1}$, dry matter, CGR, RGR and Number of primary branches and secondary branches $plant^{-1}$ were recorded at different growth stages. Yield parameters like number of siliquae $plant^{-1}$, sterile siliquae $plant^{-1}$, %sterility, siliqua length, seeds $siliqua^{-1}$, 1000-grains weight, stover yield, shell yield and grain yield were recorded after harvest. The oil content of seeds was determined by "Soxhlet" method in percentage. This was done in Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701. Data were analyzed using using the CROPSTAT (Version 7.2, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by 5% level of significance (Gomez and Gomez, 1984).

Results showed that, 37.2 kg ha^{-1} sulphur dose showed the tallest plant height (30.08, 101.28, 111.56, 111.27, 111.26 cm) throughout the lifecycle (30, 45, 60, 75 DAS and at harvest). On the other hand, 0 kg ha^{-1} sulphur dose showed the shortest plant height (20.64, 92.39, 104.76, 104.72 and 104.63 cm) throughout the lifecycle. The variation was significant. At 30 and 45 DAS, highest leaf number (11.03 and 38.7) was observed at 18.6 kg ha^{-1} sulphur dose and lowest leaf number (9.94 and 36.03) was observed at 0 kg ha^{-1} sulphur dose. At 60 DAS, maximum leaf number (86.31) was achieved by 37.2 kg ha^{-1} sulphur dose and minimum leaf number (79.22) was achieved by 27.9 kg ha^{-1} sulphur dose. At 75 DAS and at harvest, maximum leaf number (29. 47 and 11) was achieved by 0 kg ha^{-1} and 37.2 kg ha^{-1} sulphur doses respectively. Minimum leaf number (25.47 and 8.25) was achieved by 18.6 kg ha^{-1} sulphur dose. At 30 DAS, maximum dry matter accumulation (0.68 g) was achieved by S_1 and minimum dry matter accumulation (0.63 g) was achieved by S_3. At 45, 60 and 75 DAS, maximum dry matter accumulation (6.8, 13.06 and 15.14 g) was achieved by S_3 and minimum dry matter accumulation (5.04, 9.76 and 12.54 g) was achieved by S_0. At 30-45, 45-60 and 60-75 DAS, highest CGR (0.411, 0.418 and 0.185 g plant^{-1} day^{-1}) was found at S_3, S_3 and S_1 respectively and lowest CGR (0.293, 0.285 and 0.139 g plant^{-1} day^{-1}) was found at S_0, S_2 and S_3 respectively. At 30-45, 45-60 and 60-75 DAS, highest RGR (0.159, 0.045 and 0.017 g g^{-1} day^{-1}) was found at S_3, S_0 and S_0 respectively and lowest RGR (0.137, 0.034 and 0.01 g g^{-1} day^{-1}) was found at S_0, S_2 and S_3 respectively. At 30 DAS, maximum number of primary branches (3.25) was achieved by S_0 and minimum number of primary branches (2.83) was achieved by S_1. At 45, 60 and 75 DAS and at harvest, maximum number (9.25, 9.83, 9.83 and 9.92) of primary branches was found at S_1. At 45 and 60 DAS, minimum number of primary branches (8.75and 9.08) was found at S_3 and S_2 respectively. At 75 DAS and at harvest, maximum number of primary branches (9.17) was found both at S_2 and S_3. At 60 and 75 DAS and at harvest, maximum number of secondary branches (3.92, 4.33 and 4.33) was achieved at S_3 and minimum number of secondary branches (2.67, 3.33 and 3.33) was achieved by S_1.

S_3 scored the highest number (181.42) of silquae plant^{-1} and S_0 scored the lowest number (151.67) of siliquae plant^{-1}. Maximum number (7.25) of sterile siliquae plant^{-1} was recorded at S_2 and minimum number (6.03) of sterile silquae plant^{-1} was observed at S_1. Highest sterility percentage (4.48%) was recorded at S_1 and lowest sterility percentage (3.92%) was observed at S_3. Maximum siliqua length (5.05 cm) was scored at S_0 and minimum siliqua length (4.89 cm) was recorded at S_3. Maximum number of seeds siliqua^{-1} (23.06) was recorded at S_0 and minimum number of seeds siliqua^{-1} (21.4) was recorded at S_3. S_2 scored the highest shell yield (1.64 t ha^{-1}) and S_0 scored the lowest shell yield (1.01 t ha^{-1}). S_3 scored the highest (4.03 t ha^{-1}) stover yield and S_0 scored the lowest stover yield (2.89 tha^{-1}). Highest grain yield (2.96 t ha^{-1}) was obtained at S_2 and lowest grain yield (2.17 t ha^{-1}) was obtained at S_0. S_3 scored the highest (8.58 t ha^{-1}) biological yield and S_0 scored the lowest (6.08 t ha^{-1}) biological yield. Maximum harvest index (35.73%) was recorded at S_0 and minimum harvest index (34.1%) was recorded at S_3. Maximum weight of 1000-seed (3.28 g) was found at S_2 and minimum weight of 1000-seed (3.02 g) was found at S_1. Maximum oil percentage (40.19%) was gained at S_3 and minimum oil percentage (39.52%) was gained at S_0.

In terms of Boron effect, at 30 DAS, S_0 showed the tallest plant height (25.1 cm) and B_3 showed the shortest plant height (23.35 cm). At 45, 60 and 75 DAS and at harvest B_2 showed the tallest plant height (97.03, 108.76, 108.63 and 108.56 cm). At 45 DAS, B_3 showed the shortest plant height (94.7 cm). At 60 and 75 DAS and at harvest, S_1 showed the shortest plant height (107.16, 106.89 and 106.88 cm). At 30, 45, 60 and &75 DAS and at harvest, B_2, B_3, B_3, B_0 and B_3 showed the maximum leaf number (10.61, 40.06, 83.22, 28.39 and 9.83). At 30. 45, 60 and 75 DAS, maximum dry matter (0.67, 6.38, 11.14 and 13.61 g) was produced at B_1, B_3, B_0 and B_2 respectively and minimum dry matter (0.63, 5.79, 10.74 and 13.01 g) was produced at B_0, B_2, B_1 and B_1 respectively. On 30-45, 45-60 and 60-75 DAS, highest CGR (0.381, 0.343 and 0.183 g $plant^{-1}$ day^{-1}) was scored at B_3, B_0 and B_2. Lowest CGR (0.343, 0.313 and 0.151 g $plant^{-1}$ day^{-1}) was found at B_2, B_1 and B_1. On 30-45 DAS, highest RGR (0.15 g g^{-1} day^{-1}) was recorded both at B_0 and B_3 and lowest RGR (0.146 g g^{-1} day^{-1}) was found both at B_1 and B_2. On 45-60 and 60-75 DAS, highest RGR (0.043 and 0.015 g g^{-1} day^{-1}) was scored at B_2. At 45-60 DAS, lowest RGR (0.037 g g^{-1} day^{-1}) was found at B_3. At 60-75 DAS, lowest RGR (0.013 g $^{-1}$ day^{-1}) was found both at B_0 and B_1. At 30 DAS, maximum number (3.17) of primary branches were recorded both at B_0 and B_1 and minimum number (2.67) of primary branches were found at B_3. At 45, 60 and 75 DAS and at harvest, maximum number (9.42, 9.75, 9.83 and 9.83) of primary branches were recorded both at B_0 and minimum number (8.75, 9.08, 9.08 and 9.17) of primary branches were found at B_1. At 60 and 75 DAS and at harvest, B_1 scored the maximum number of secondary branches (3.25, 4 and 4). At 60 DAS, minimum number (2.92) of secondary branches were recorded at B_3. At 75 DAS and at harvest, minimum number (3.58) of secondary branches were found both at B_0 and B_3.

B_3 scored the highest number (194.75) of silquae plant^{-1} and B_0 scored the lowest number (126.67) of siliquae plant^{-1}. Maximum number (7.06) of sterile siliquae plant^{-1} was recorded at B_1 and minimum number (6.25) of sterile silquae plant^{-1} was observed at B_2. Highest sterility percentage (5.58%) was recorded at B_0 and lowest sterility percentage (3.32%) was observed at B_2. Maximum siliqua length (5.16 cm) was scored at B_0 and minimum siliqua length (4.89 m) was recorded at B_3. Maximum number of seeds siliqua^{-1} (22.86) was recorded at B_3 and minimum number of seeds siliqua^{-1} (21.63) was recorded at B_2. B_2 scored the highest shell yield (1.48 t ha^{-1}) and B_1 scored the lowest shell yield (1.27 t ha^{-1}). B_3 scored the highest (3.6 t ha^{-1}) stover yield and B_0 scored the lowest (3.53 t ha^{-1}) stover yield. Highest grain yield (2.73 t ha^{-1}) was obtained at B_2 and lowest grain yield (2.53 t ha^{-1}) was obtained at B_0. B_2 scored the highest (7.79 t ha^{-1}) biological yield and B_1 scored the lowest (7.33 t ha^{-1}) biological yield. Maximum harvest index (35.08%) was recorded at B_2 and minimum harvest index (34.6%) was recorded at B_0. Maximum weight of 1000-seed (3.19 g) was found at B_2 and minimum weight of 1000-seed (3.03 g) was found at B_3. Maximum oil percentage (40.42%) was gained at B_2 and minimum oil percentage (40.17%) was gained at B_0.

In terms of Interaction effect of Sulphur and Boron, at 30 and 45 DAS tallest plant height (33.11 and 103 cm) was found at S_3B_0. At 30 DAS shortest plant height (20.11 cm) was observed at S_0B_1. At 45 DAS, shortest plant height (90.45) was observed at S_0B_3. At 60 and 75 DAS and at harvest S_3B_2 showed the tallest plant height (113.48, 113.18 and 113.18 cm) and S_0B_0 scored the shortest plant height (102.73, 103.08 and 102.96 cm). At 30, 45, 60 and &75 DAS and at harvest, S_1B_1, S_0B_3, S_1B_3, S_3B_1 and S_0B_2 respectively showed the maximum leaf number (11.67, 42.56, 89.89, 32.67 and 11.67). On the other hand, S_0B_0, S_0B_0, S_2B_3, S_1B_1 and S_1B_1 scored the minimum leaf number (9.11, 31.78, 72.22, 20.22 and 6.33). At 30 DAS maximum dry matter (0.72 g) was accumulated at S_1B_2 and minimum dry matter (0.58 g) was accumulated at S_3B_2. At 45, 60 and 75 DAS, maximum dry matter (7.83, 13.84, 16.8 g) was produced at S_3B_3.At 45 DAS, minimum dry matter (4.59 g) was produced at S_0B_2. At 60 and 75 DAS minimum dry matter (9.62 and 12.07 g) was produced at S_0B_3. On 30-45, 45-60 and 60-75 DAS, highest CGR (0.479, 0.468 and 0.267 g plant^{-1} day^{-1}) was scored at S_3B_3, S_3B_0 and S_0B_2. Lowest CGR (0.265, 0.236 and 0.088 g plant^{-1} day^{-1}) was found at S_0B_2, S_1B_1 and S_3B_1. On 30-45 DAS, highest RGR (0.166 g g^{-1} day^{-1}) was recorded at S_3B_3 and lowest RGR (0.13 g g^{-1} day^{-1}) was found at S_1B_2. On 45-60 DAS highest RGR (0.05 g g^{-1} day^{-1}) was found both at S_0B_2 and S_1B_2 and lowest RGR (0.03 g g^{-1} day^{-1}) was found both at S_1B_1 and S_2B_2. At 30 DAS, maximum number (3.67) of primary branches were recorded at S_0B_1 and minimum number (2) of primary branches were found at S_1B_3. At 45, 60 and 75 DAS and at harvest, maximum number (10, 10.33, 10.67 and 10.67) of primary branches were recorded both at S_2B_0. At 45 DAS, minimum number (8.33) of primary branches were found at S_3B_1. At 60 and 75 DAS and at harvest, minimum number (8.33) of primary branches were found at S_2B_2. At 60 and 75 DAS and at harvest, S_3B_3 scored the maximum number of secondary branches (4.67, 5 and 5). At 60 DAS, minimum number (2) of secondary branches were recorded at S_1B_3. At 75 DAS and at harvest, minimum number (3) of secondary branches were found at three treatments namely S_1B_2, S_1B_3 and S_2B_3.

S_3B_3 scored the highest number (209.67) of silquae plant^{-1} and S_0B_0 scored the lowest number (112) of siliquae plant^{-1}. Maximum number (8) of sterile siliquae plant^{-1} was recorded at S_2B_3 and minimum number (5.33) of sterile silquae plant^{-1} was observed at S_0B_2. Highest sterility percentage (5.33%) was recorded at S_2B_0 and lowest sterility percentage (3.03%) was observed at S_3B_2. Maximum siliqua length (5.33 cm) was scored at S_2B_0 and minimum siliqua length (4.74 cm) was recorded at S_2B_1. Maximum number of seeds siliqua^{-1} (25.2) was recorded at S_1B_3 and minimum number of seeds siliqua^{-1} (19.43) was recorded at S_2B_2. S_2B_2 scored the highest shell yield (1.73 t ha^{-1}) and S_0B_0 scored the lowest shell yield (0.87 t ha^{-1}). S_3B_1 and S_3B_3 scored the highest (4.04 t ha^{-1}) stover yield and S_0B_0 scored the lowest (2.8 t ha^{-1}) stover yield. Highest grain yield (3.07 t ha^{-1}) was obtained at S_2B_2 and lowest grain yield (2.1 t ha^{-1}) was obtained at S_0B_0. S_3B_2 scored the highest (8.76 t ha^{-1}) biological yield and S_0B_0 scored the lowest (5.83 t ha^{-1}) biological yield. Maximum harvest index (36.07%) was recorded at S_0B_0 and minimum harvest index (33.55%) was recorded at S_3B_0. Maximum weight of 1000-seed (3.83 g) was found at S_2B_1 and minimum weight of 1000-seed (2.81 g) was found at S_3B_1. Maximum oil percentage (41.32%) was gained at S_3B_2 and minimum oil percentage (39.41%) was gained at S_0B_1.

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Appendices

APPENDIX–I:

The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth).

Physical composition

Sand : 40%

Silt : 40%

Clay : 20%

Texture : Loamy

Chemical composition

Constituents’	: 0-15 cm depth
pH	: 6.4
Total N (%)	: 0.07
Available P (μ g/g)	: 18.49
Exchangeable K (meq)	: 0.07
Available S (μ g/g)	: 20.82
Available Fe (μ g/g)	: 229
Available Zn (μ g/g)	: 4.48
Available Mg (μ g/g)	: 0.825
Available Na (μ g/g)	: 0.32
Available B (μ g/g)	: 0.94
Organic matter (%)	: 1.4

The soil sample was analyzed by Soil Resources Development Institute (SRDI), 2013

APPENDIX-II

Monthly records of Temperature, Rainfall and Relative humidity of the experiment site during the period from November 2013 to February 2014.

Year	Month	Air temperature (^{O}c)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Mean		
2013	November December	29.5 26.9	18.6 16.2	24.0 21.5	69.5 70.6	0.0 0.0
2014	January February	24.5 28.9	13.9 18.0	19.2 23.4	68.5 61.0	4.0 3.0

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

APPENDIX-III: Photographs of experiment

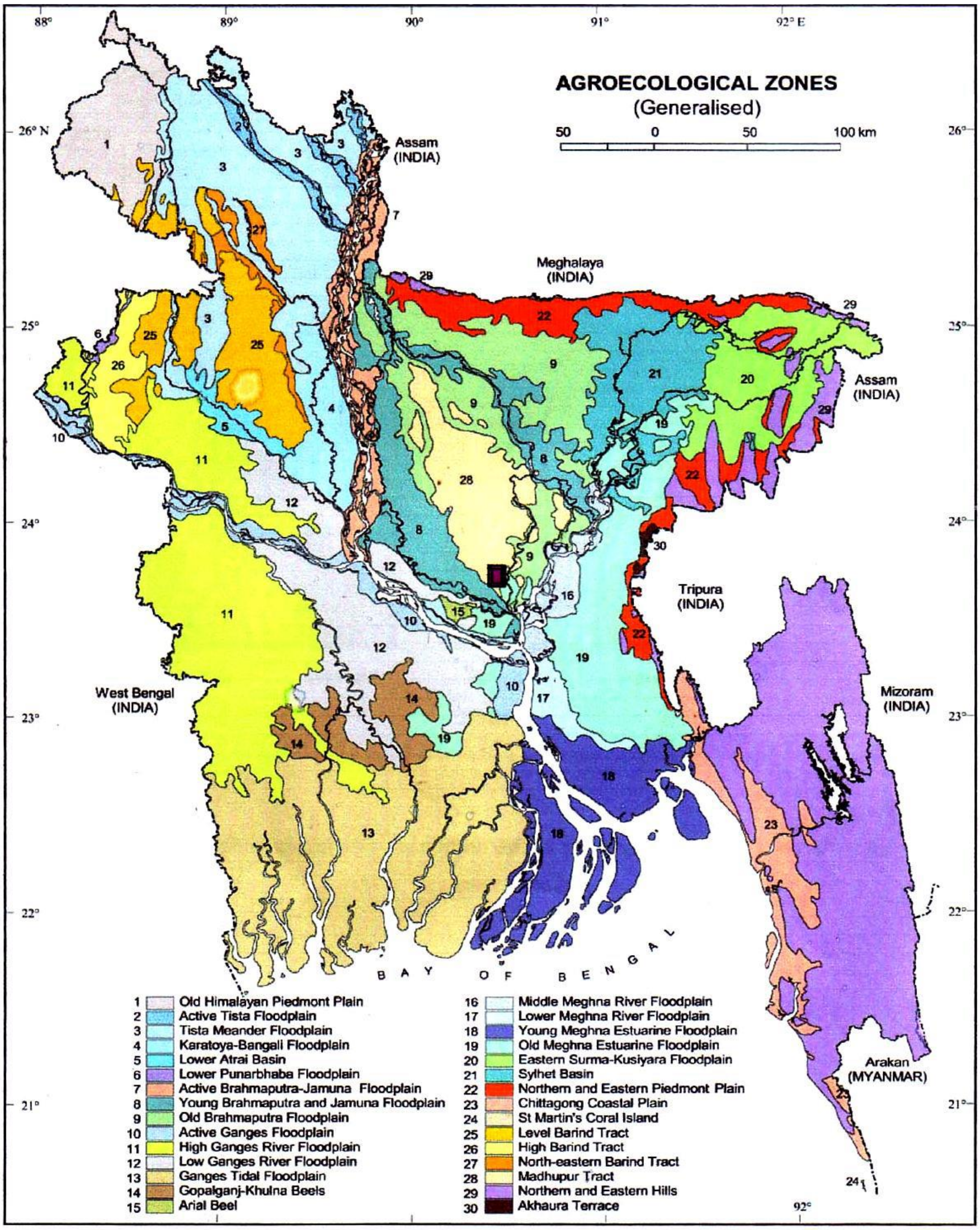
Plate 1. Photograph showing seed coat colour, seed size and shape of BARI Sarisha-15

Plate 2. A view of the experimental plot

Plate 3. A view of the experimental plot

Plate 4. Effect of boron to siliqua formation

Appendix IV. Map showing the experimental site under study



APPENDIX-V:

Means square values for growth, yield and other yield attributes

1. Plant height

Source of Variation	DF	Means square values at different days after sowing				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	8.15^{ns}	62.22^{*}	14.84^{ns}	13.42^{ns}	11.75^{ns}
Sulphur doses	3	200.24^{*}	167.93^{*}	98.46^{*}	89.81^{*}	92.73^{*}
Boron doses	3	6.94^{ns}	14.31^{ns}	5.14^{ns}	6.15^{ns}	5.8^{ns}
S×B	9	6.9^{ns}	10.58^{ns}	8.25^{ns}	6.72^{ns}	6.8^{ns}
Residuals	30	3.61	13.31	9.94	9.71	9.76

* Significant at 5% level
ns- Non significant

2. Leaf number

Source of Variation	DF	Means square values at different days after sowing				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	1.18^{ns}	56.98^{ns}	260.6^{ns}	10.53^{ns}	1.08^{ns}
Sulphur doses	3	4.03^{ns}	24.12^{ns}	115.03^{ns}	52.76^{ns}	23.3^{*}
Boron doses	3	0.55^{ns}	42.96^{ns}	17.88^{ns}	16.24^{ns}	1.02^{ns}
S×B	9	1.07^{ns}	18.93^{ns}	51.43^{ns}	47.47^{ns}	2.78^{ns}
Residuals	30	1.56	27.57	116.92	19.08	2.53

* Significant at 5% level
ns- Non significant

3. Dry matter weight

Source of Variation	DF	Means square values at different days after sowing			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.035^{*}	0.078^{ns}	1.01^{ns}	1.05^{ns}
Sulphur doses	3	0.006^{ns}	7.44^{*}	27.15^{*}	16.79^{*}
Boron doses	3	0.004^{ns}	0.727^{ns}	0.42^{ns}	0.873^{ns}
S×B	9	0.006^{ns}	0.926^{ns}	0.81^{ns}	2.13^{*}
Residuals	30	0.005	0.815	0.953	0.729

* Significant at 5% level
ns- Non significant

4. Crop growth rate (CGR)

Source of Variation	DF	Means square values at different days after sowing		
		30-45 DAS	45-60 DAS	60-75 DAS
Replication	2	0.0008^{ns}	0.007^{ns}	0.013^{ns}
Sulphur doses	3	0.034^{*}	0.045^{*}	0.005^{ns}
Boron doses	3	0.003^{ns}	0.003^{ns}	0.003^{ns}
S×B	9	0.004^{ns}	0.006^{ns}	0.005^{ns}
Residuals	30	0.003	0.008	0.005

* Significant at 5% level
ns- Non significant

5. Relative growth rate (RGR)

Source of Variation	DF	Means square values at different days after sowing		
		30-45 DAS	45-60 DAS	60-75 DAS
Replication	2	0.00056^{*}	0.00009^{ns}	0.00007^{ns}
Sulphur doses	3	0.0012^{*}	0.00031^{ns}	0.0001^{*}
Boron doses	3	0.00006^{ns}	0.00008^{ns}	0.00001^{ns}
S×B	9	0.00017^{ns}	0.00011^{ns}	0.00003^{ns}
Residuals	30	0.00014	0.00013	0.00003

* Significant at 5% level
ns- Non significant

6. Number of primary branches

Source of Variation	DF	Means square values at different days after sowing				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.438^{ns}	1.57^{ns}	0.271^{ns}	0.188^{ns}	0.083^{ns}
Sulphur doses	3	0.389^{ns}	0.688^{ns}	1.41^{ns}	1.3^{ns}	1.58^{ns}
Boron doses	3	0.667^{ns}	1.09^{ns}	1.24^{ns}	1.35^{ns}	1.14^{ns}
S×B	9	0.315^{ns}	0.694^{ns}	0.836^{ns}	1.24^{ns}	1.31^{ns}
Residuals	30	0.771	0.579	0.582	0.676	0.661

* Significant at 5% level
ns- Non significant

7. Number of secondary branches

Source of Variation	DF	Means square values at different days after sowing		
		60 DAS	75 DAS	At harvest
Replication	2	0.58^{ns}	0.771^{ns}	0.771^{ns}
Sulphur doses	3	3.91^{*}	2.31^{*}	2.31^{*}
Boron doses	3	0.243^{ns}	0.472^{ns}	0.472^{ns}
S×B	9	0.965^{ns}	0.694^{ns}	0.694^{ns}
Residuals	30	1.01	0.593	0.593

* Significant at 5% level
ns- Non significant

8. Siliqua plant^{-1}, Sterile Siliqua plant^{-1}, Sterility percentage, Siliqua length, Seed siliqua^{-1}

Source of Variation	DF	Means square values at different days after sowing				
		Siliqua plant^{-1}	Sterile Siliqua plant^{-1}	Sterility percentage	Siliqua length	Seed siliqua^{-1}
Replication	2	5243.15^{*}	6.91^{*}	0.129^{ns}	0.05^{ns}	2.14^{ns}
Sulphur doses	3	1998.24^{*}	3.33^{ns}	0.679^{ns}	0.06^{ns}	7.26^{ns}
Boron doses	3	12070.1^{*}	1.68^{ns}	13.15^{*}	0.173^{*}	3.52^{ns}
S×B	9	58.002^{ns}	0.911^{ns}	0.563^{ns}	0.047^{ns}	8.23^{*}
Residuals	30	61.06	1.44	0.478	0.026	3.38

* Significant at 5% level
ns- Non significant

9. Stover yield, Straw yield, Grain yield, Biologcal yield, Harvest index

Source of Variation	DF	Means square values at different days after sowing			
		Stover yield	Straw yield	Grain yield	Biologcal yield
Replication	2	0.081*	0.534*	0.632*	3.19*
Sulphur doses	3	1.09*	3.21*	1.69*	17.03*
Boron doses	3	0.11*	0.013ns	0.105*	0.581*
S×B	9	0.0005ns	0.003ns	0.002ns	0.003ns
Residuals	30	0.0015	0.0045	0.004	0.01

* Significant at 5% level
ns- Non significant

10. 1000-seed weight, Oil percentage, Growth duration, Yield day^{-1}

Source of Variation	DF	Means square values at different days after sowing		
		Harvest index	Oil percentage	1000-seed weight
Replication	2	4.21*	0.186ns	0.0063ns
Sulphur doses	3	5.38*	6.63*	0.174ns
Boron doses	3	0.481ns	0.141ns	0.066ns
S×B	9	0.354ns	0.069ns	0.197*
Residuals	30	0.372	0.091	0.087

* Significant at 5% level
ns- Non significant