EFFECTS OF IRRIGATION AND SULPHUR ON GROWTH, YIELD AND OIL CONTENT OF RAPESEED

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JUNE, 2014

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BY

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REGISTRATION NO. 07-02369

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
In partial fulfillment of the requirements
For the degree of

MASTER OF SCIENCE

IN

AGRICULTURAL CHEMISTRY

SEMESTER: JANUARY-JUNE, 2012

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CERTIFICATE

This is to certify that thesis entitled, "**EFFECTS OF IRRIGATION AND SULPHUR ON GROWTH, YIELD AND OIL CONTENT OF RAPESEED**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURAL CHEMISTRY,** embodies the result of a piece of *bona fide* research work carried out by **Kanak Chandra Roy**, **Registration No. 07-02369** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any institute.

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.

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ACKNOWLEDGEMENTS

At the outset, the author would like to express his profound gratefulness to ***the Almighty God*** *to confer blessing in compiling this research work.*

The author intends to extend his deepest sense of gratitude and respect to his Supervisor ***Dr. Md. Abdur Razzaque,*** *Professor, Department of Agricultural Chemistry, Sher-e- Bangla Agricultural University (SAU), Dhaka-1207 for his guidance during the research work and constructive criticism to improve the manuscript.*

The author feels proud in expressing his sincere gratitude and indebtedness to his research Co-Supervisor ***Dr. Rokeya Begum,*** *Professor, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 for her valuable suggestions, continuous and cordial help to complete the study successfully.*

The author wishes to express deepest gratitude, profound appreciation and immense indebtedness to all the teachers and staff members of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 for their co-operation and support during the study.

Heartiest thanks and gratitude are due to Farm Division of Sher-e-Bangla Agricultural University for their support to conduct the research.

The service from the library of Sher-e-Bangla Agricultural University, Bangladesh Agricultural Research Council information Centre, Bangabandhu Sheikh Mujibur Rahman Agricultural University is acknowledged with thanks.

The author wishes his profound gratitude to his parents, and elder brother for inspiring him in preparing the manuscript. He also expresses his cordial thanks to all of his friends specially Md. Arifur Rahman, Pretom Kumar Hore and cousin, Repon Chandra Roy for encouragement and help.

May God bless and protect them all.

June, 2014 The Author

EFFECTS OF IRRIGATION AND SULPHUR ON GROWTH, YIELD AND OIL CONTENT OF RAPESEED

ABSTRACT

An experiment was conducted at the agronomy field of Sher-e-Bangla Agricultural University during the period of October 2013 to February 2014 to examine the effect of irrigation and sulphur on the growth, yield and oil content of rapeseed (*Brassica campestries*). There were three different levels of irrigation viz. no irrigation, once at 25 DAS and twice at 25 DAS and 53 DAS and three levels of sulphur viz. 15, 30 and 45 kg S ha^{-1}. The experiment was laid out in split plot design with three replications assigning irrigation in the main plots and levels of sulphur in the subplot. Irrigation and sulphur significantly influenced the growth, development, yield and yield attributes of rapeseed. Plant height, number of primary branches per plant, secondary branches per plant, number of siliquae per plant, siliquae length, seeds per siliquae, seed yield and oil content was significantly influenced by both irrigation and sulphur. Among the irrigation treatments, two irrigation levels resulted the better growth parameters like plant height and yield components like number of primary branches per plant, secondary branches per plant, number of siliquae per plant, siliquae length, seeds per siliqua and seed yield. Irrigation levels also influenced the oil content. Twice irrigation levels showed the best performance in all respect. The highest seed yield 1505 kg ha^{-1} was obtained from twice irrigation levels while control treatment gave the lowest yield. The result revealed that application of 45 kg S ha^{-1} showed superior in all respect which is statistically similar to the application of 30 kg S ha^{-1} except oil content. The interaction effect of irrigation and sulphur revealed that twice irrigation levels in combination with 45 kg S ha^{-1} showed the best performance which was statistically similar to twice irrigations with 30 kg S ha^{-1}.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full words
FAO	Food and Agriculture Organization
BBS	Bangladesh Bureau of Statistics
BCSIR	Bangladesh Council of Scientific & Industrial Research
LSD	Least significant difference
et al.	Et alibi (and others)
i.e.	That is
kg	Kilogram
lb.	Pound
mt	Metric-ton
µl	Micro liter
µg	Micro gram
ng	Nanogram
OP	Organophosphorus
Op	Ortho para
pp	Parapara
ppb	Parts per billion
ppm	Parts per million
PR	Pesticide residue
%	Percentage
g	Gram
ai	Active ingredient
t	Ton
cm^2	Square centimeter
yr	Year
m^2	Square meter
cm^3	Cubic centimeter (Solid)
m	Meter
df	Degree of freedom
ha	Hectare
SE	Standard error
pH	Negative log of Hydrogen ion concentration
Yd	Yard
wk	Week
A	Acre
NS	Not Significant
BARI	Bangladesh Agricultural Research Institute

CHAPTER I

INTRODUCTION

Rapeseed and mustard belong to the family Cruciferae are important crops and currently ranked as the world's third important oil seed crop in terms of production and area. Among the species, *Brassica napus* and *Brassica campestris* are regarded as rapeseed while *Brassica juncea* is regarded as mustard. Rapeseed and mustard contain 40-45% oil and 20-25% protein in seed. Edible oil is a high-energy component of food and meeting the calorie requirements of human nutrition. It is one of the basic requirements of our daily diet. Each gram of oil supplies 9 kcal energy whereas 4 kcal energy comes from one gram carbohydrate or protein (Stryer, 1980). Bangladesh has been facing acute shortage of edible oil for the last several decades (BBS, 2012). According to the National Nutrition Council (NNC) of Bangladesh, the recommended dietary allowance (RDA) is estimated to be 11 g oil capita^{-1} day^{-1} for a diet with 2700 kcal (NNC, 1984). On the basis of RDA, Bangladesh requires 0.29 million tons of oil to meet the demand of her people (FAO, 2008). About one-third of the total requirement of oil is met by local production of rapeseed and mustard (BBS, 2012).

At present about 0.25 million hectares of land is under rapeseed and mustard cultivation in Bangladesh with a production of 0.246 million tons (BBS, 2012). The average seed yield of rapeseed and mustard is 0.976 t ha^{-1} in this country (BBS, 2012), which is far below the level as compared to that of the advanced countries like Belgium (4.7 t ha^{-1}), Denmark (3.6 t ha^{-1}), France (3.54 t ha^{-1}), Netherlands (3.47 t ha^{-1}), U .K. (2.89 t ha^{-1}), Germany (2.8 t ha^{-1}), Japan (2.16 t ha^{-1}) and Poland (1.86 t ha^{-1}) FAO (2012). The major reasons for such poor yield of mustard in Bangladesh may be attributed to lack of improved varieties and poor management practices in the farmers' field.

On the contrary, the National Agricultural Research System (NARS) Institutes and Agri-universities of the country developed a number of *Brassica* oilseed varieties with high yield potentials suitable for cultivation in between Aman and Boro rice with improved package of management practices. The yield of these cuitivars ranges between 1.4 and 2.1 t ha^{-1} (BARI, 2012). However, the yields in farmers' fields are still low compared to their potentiality due to lack of proper management practices. Therefore, there is a scope to increase the yield level by using HYV and adopting proper management practices like spacing, weeding, irrigation, seed rate, fertilizer application etc.

In Bangladesh both rapeseed and mustard are grown on the residual soil moisture in rabi season (Kaul and Das, 1986). But irrigation is a vital factor for proper growth and development of these crops in dry season (Roy and Tripathi, 1985). The crop essentially requires water ranging from 60 to 169 mm through its life cycle (Rahman, 1989; Sarkar *et al*., 1989). In fact *Brassica* is an irrigated crops since its yields is greatly increased by the presence of adequate soil moisture in different growth stages (Prasad and Eshanullah, 1988). Irrigation has been found to increase 1000 seed weight, number of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$, seed yield and harvest index (Shrivastava *et al*., 1988). Mondal *et al*. (1988) reported that one irrigation at flowering and another at siliquae development stages gave the highest yield (2.56 t ha^{-1}). Irrigation has also an effect in increasing the fertilizer uptake thus increasing biomass, which ultimately increased yield.

Sulphur has also been reported to influence productivity of oil seed (Singh *et al*., 1999). Similarly, Biswas *et al*. (1995) reported that application of S fertilizer increased the seed yield of mustard cultivars.

Rapeseed has a high demand of S, with approximately 16 kg of S required to produce 1.0 ton of seeds containing 91% of dry matter (Zhao *et al*., 1993; McGrath *et al*., 1996). Several authors are of the opinion that oilseeds not only respond to applied S, but their requirement for S is also the highest among other crops, thereby attributing a role for the nutrient in oil biosynthesis (Fazili *et al*, 2005; Ahmad *et al*, 2000; Ahmad *et al*., 2007; Munshi *et al*., 1990). Sulphur is an important nutrient and plays an important role in physiological functions like synthesis of cystein, methionine, chlorophyll and oil content of oil seed crops. It is also responsible for synthesis of certain vitamins (B, Biotin and thiamine), metabolism of carbohydrates, proteins and oil formation of flavoured compounds in crucifers. *Brassica* has the highest sulphur requirement owing to the presence of sulphur rich glucosinolates. Oilseed crops respond to sulphur application remarkably depending on soil type and source of its use.

Sulphur deficiency symptoms include reduced plant growth and chlorosis of the younger leaves, beginning with intervainal yellowing that gradually spreads over the entire leaf area. Sulphur is somewhat immobile in the plant, so that deficiency symptoms tend to occur first in younger leaves. Plants may be small and spindly with short, slender stalks. As the deficiency becomes more severe, leaf cupping and a more erect leaf structure is often observed (Franzen and Grant, 2008). Plants grow slowly and maturity may be delayed. Plants may flower but have reduced seed set as is the case for rapeseed. Sulphur increases dry matter in plant and thus it is effective on growth analyses. Mandal and Sinha (2004) reported that dry matter production and Cumulative Growth Rate (CGR) significantly increased with increasing level of sulphur up to 20 kg S ha^{-1} and Leaf area index up to 40 kg S ha^{-1}.

Taking the above mentioned points in view, the present study was undertaken with the following objectives:

a) To find out the minimum number of irrigation for getting higher yield,
b) To find out the suitable level of sulphur fertilizer for the cultivation of rapeseed plant and
c) To study the effect of irrigation and sulphur on growth, yield and oil content of rapeseed.

CHAPTER II

REVIEW OF LITERATURE

Rapeseed is an important oil crop in Bangladesh, which can contribute largely in the national economy. But the research works done on this crop are inadequate. Proper irrigation and fertilizer management accelerates its growth and influenced its yield as well as oil content. Therefore, available findings of the direct effect of irrigation and sulphur fertilizer and combination effect relevant to the present study have also been briefly reviewed under the following heads:

2.1 Effect of irrigation

Seed yield of *Brassica* is greatly affected by water stress during flower initiation and siliquae filling stage (Richard and Thurling, 1978). Singh *et al.* (2002) tested four *Brassica* spp. (*Brassica carinata, Brassica napus, Brassica juncea* and *Brassica campestris*) under 2 moisture regimes, i.e. normal irrigation (3 irrigations at branching, bolting and filling stages) and limited irrigation (one irrigation at branching stage). Results regaled that growth, development and yield of all *Brassica* spp. were adversely affected under limited irrigation condition. This clearly indicates that yield expression of *Brassica* spp. differs under varying soil water environment.

2.1.1 Plant Height

Siag *et al.* (1993) found a relationship between irrigation levels and plant height of Toria. In an experiment, plant height was increased with the increasing levels of irrigation. Plant height was 120.5 cm with 2 irrigations at branching and siliquae development stage and it was the highest compared to 113.0 cm and 108.7 cm with one irrigation at branching stage and without irrigation respectively.

Saran and Giri (1988) reported that plant height was found to be highest when one irrigation at 30 DAS was applied. But two irrigations applied at 30 and 60 DAS produced more plant height than under rainfed condition. There was a significant relationship between irrigation levels and plant height.

2.1.2 Dry matter accumulation

Giri (2001) reported that dry matter per plant was not significantly increased with irrigation treatments. He conducted two experiments to find out the effect of irrigation on growth and yield of mustard. Dry matter production was 107.1 g plant^{-1} with two irrigations at flowering and siliquae development stage, which was higher than the dry matter produced with one irrigation at flowering stage but one irrigation, produced higher dry matter than two irrigation.

Raut *et al*. (1999) studied the effects of irrigation (at pre-flowering and siliquae- setting stages, pre-flowering + 50% flowering + siliquae setting stages, pre-flowering + 50% flowering + seed filling stages and pre-flowering + 50% flowering + siliquae-setting + seed filling stages) on the dry matter production and yield of Indian mustard cv. Pusa Bold. Irrigations once at pre-flowering + 50% flowering + siliquae-setting + seed-filling stages gave the highest dry matter, production at 30 (1.2 g pre-flowering + 50% flowering + seed filling stages gave the highest dry matter production at 90 DAS (74.0 g per plant) and at harvest (112.25 g per plant) as well as the highest grain yield (15.99 q ha^{-1}).

A field experiment was conducted by Mahal *et al*. (1995) during the Rabi seasons of 1987 and 1988 at Ludhiana. Toria was irrigated at 50, 60 or 70% depletion of available soil moisture. The dry matter of leaves, stems and siliquae increased with irrigation at lower depletion levels.

Gill and Narang (1993) observed distinct differences in dry matter production after 70 DAS in case of mustard, when differential irrigation schedule were maintained. Three irrigations (one at 28 DAS and 2 at 80 mm CPE) produced maximum diy matter, being significantly more than that produced by one and two irrigations at all the growth stages.

Paul and Begum (1993) showed that total dry matter weight of different irrigation treatment at successive stage of growth of rapeseed was significant except the first harvest (38 DAS). The plant receiving continuous irrigation throughout the growing period had the highest dry weight while rainfed plant had the lowest total dry weight. Among the remaining treatments, irrigation at 50% flowering stage prove to be the most important single irrigation treatment. Two irrigation also increased dry matter production.

Tomer *et al.* (1992) found increased dry matter production in mustard with increasing number of irrigation. They conducted an experiment with no irrigation, one irrigation at pre-flowering and two irrigations (one at pre-flowering and another at fruiting). Significant increase in dry matter was found up to two irrigation. The maximum dry matter production was found to be 102.37 g with two irrigations while one irrigation and control (no irrigation) produced 90.61 g and 67.75 g dry matter per plant respectively.

Patel *et al.* (1991) found a significant difference in case of dry matter accumulation in mustard with application of irrigation. One irrigation produced more dry matter (53.2 g plant^{-1}) which was significantly higher than that was produced without irrigation (47.0 g plant^{-1}).

2.1.3 Number of branches plant^{-1}

Singh *et al.* (2002) conducted a field trial with *Brassica juncea* irrigated at 50% flowering, at 50% flowering + 50% siliquae development, or given no post-sowing irrigations. They found the maximum branching with increased irrigation level.

Tomer *et al*. (1992) concluded that branches per plant of rapeseed were significantly increased with irrigation. Branches per plant were highest with two irrigation compared to one irrigation or without irrigation (control). They reported that branches per plant were 40.29 when two irrigations were applied at pre-flowering and fruiting stage. When one irrigation was applied at pre-flowering stage it produced 33.00 branches per plant. The least number of branches (26.56) was produced at control treatment.

Patel *et al*. (1991) found that irrigation produced higher number of branches of mustard than unirrigated condition in another experiment, one irrigation produced significantly higher number of branches compared to control.

Rathore and Patel (1989) found the number of branches plan^{-1} of mustard increased with increased in irrigation frequency.

Prasad and Ehsanullah (1988) reported that number of primary branches of mustard was significantly increased with irrigation levels. They found maximum number of primary branches (5.7) per plant with two irrigations at 30 and 60 DAS which was followed by 4.3 and 4.1 with one irrigation at 30 DAS and without irrigation respectively. No significant difference was found among the irrigation treatments on primary branches plant $^{-1}$, because of high rainfall.

2.1.4 Number of siliquae plant^{-1}

Giri (2001) found that in case of two irrigation 277 siliquae were found in mustard at flowering and siliquae formation stage followed by 224 siliquae per plant with one irrigation at flowering stage. But the difference was not significant.

Sharma and Kumar (1989b) found in another experiment with mustard that the number of siliquae plant^{-1} increased with increasing irrigation frequency, while irrigation was applied with zero and one level at the rosette or at siliquae formation stage.

2.1.5 Length of siliquae

Singh and Saran (1992) observed in an experiment with *Brassica campestris* during the winter seasons of 1987-1989 that irrigation at IW and CTE ratio of 0.4 and 0.2 (two and one irrigation, respectively) gave average siliquae length of 6.1 and 6.2 cm, respectively compared to 5.5 cm from the control treatment. Final plant height, leaf-area index (60 DAS) and dry matter ha^{-1} changed favorably with an increasing in irrigation regime up to 0.4 IW: CPE (irrigation water depth and cumulative potential evaporation ratio), whereas, siliquae length significantly increased only up to 0.2 IW : CPE (irrigation water depth and cumulative potential evaporation ratio).

2.1.6 Number of seeds siliqua^{-1}

Patel *et al*. (2004) reported that one irrigation produced 465 siliquae per plant while 327 siliquae were produced per plant without irrigation.

Siag *et al*. (1993) found that when two irrigations were given either at branching and siliquae development or at branching and flowering stages recorded a significant increase in siliqua plant^{-1}. The highest number of siliquae (261) was found with two irrigations at branching and siliquae development stages.

Tomer *et al*. (1992) conducted an experiment to observed the effect of irrigation on the growth and yield of mustard (*Brassica juncea*). They tested three irrigation treatments viz. no irrigation, one irrigation (at pre-flowering stage) and two irrigation (one at pre-flowering stage and one at fruiting stage). Maximum number of siliquae (523.16) was found per plant when two irrigations were applied. One irrigation and without irrigation produced 422.83 and 332.45 siliquae per plant respectively.

Tomer *et al*. (1992) reported that seeds per silquae were also significantly increased with irrigation. Maximum number of seeds per siliqua were found when two irrigations were applied (one at pre-flowering stage and one at fruiting stage). A siliqua produced 12.36 seeds on an average when two irrigations were applied while one irrigation and without irrigation produced 10.81 and 8.02 seeds siliqua^{-1} respectively.

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

Prasad and Ehsanullah (1988) found an increasing trend of seeds siliqua^{-1} in mustard with irrigation levels. The maximum number of seeds (12.0) per siliqua was found when irrigation was applied at 30 and 60 DAS. It was followed by irrigation at 30 DAS and without irrigation which produced 10.8 and 10.0 seeds siliqua^{-1}.

2.1.7 Weight of 1000 seeds and seed yield

Tomer *et al*. (1992) reported that maximum weight of 1000 seed was found when one irrigation was applied during pre-flowering stage and another one during fruiting stage. Least weight of 1000 seed was found without irrigation.

Sharma and Kumar (1989a) observed that 1000 seed weight and seed yield were higher, when irrigation was applied at irrigation depth and cumulative pan evaporation ratio of 0.6. Thousand seed weight and seed yield were lower with irrigation to a ratio of 0.4 or without irrigation.

Prasad and Ehsanullah (1988) reported that irrigation significantly increased the1000 seed weight. They found maximum weight of 1000 seeds (4.6 g) from the application of two irrigations at 30 and 60 DAS. The lowest weight of 1000 seed (4.0g) was found in rainfed condition (without irrigation) which was lower than the application of one irrigation at 30 DAS that produced 4.2g. Two irrigations with six cm irrigation at irrigation water depth and cumulative pan evaporation ratio of 0.8 or at 30 and 60 DAS gave seed yields of 1.81-1.83 t ha^{-1} compared to 1.18-1.49 t ha^{-1} with one irrigation and 0.99-1.05 t ha^{-1} without irrigation.

Singh *et al*. (1997) reported that the stages most sensitive to water stress were the seedling stage followed by the flowering stage. Decrease in seed yield varied from 22.13 to 36.57% when irrigation was applied at seedling and flowering stages, 17.98 to 32.43% when irrigation was applied at seedling and seed development stages, and 1.59 to 3.45% when irrigation was applied at the seed development stage compared with irrigation applied at all these stages. However, early water stress from flowering to seed development stages decreased the yield by 4.83 to 15.46% compared with irrigation at all 3 stages.

Samadder *et al*. (1997) studied the *Brassica juncea* cv. Bliagirathi with non-irrigated condition and irrigation at flowering or at flowering + seed formation stages and found that seed yield was highest (1.49 t ha^{-1}) with 2 irrigations.

Mahal *et al*. (1995) reported that maximum seed yield (1.96 t ha^{-1} in 1987 and 1.66 t ha^{-1} in 1988) was recorded with 2 irrigations (at 3-4 weeks and at 9-10 weeks after sowing).

Tiwari and Chaplot (1993) conducted a field experiment on the effect of irrigation levels on mustard (*Brassica jancea* cv. Varuna) which was irrigated at vegetative, flowering, siliquae development or seed filling stage corresponding 3, 6, 9, or 12 weeks after sowing (WAS) or at various combinations of these dates. Seed yields increased with increase in irrigation frequency. The highest mean seed yield of 1.09 t ha^{-1} was obtained from irrigating the crop at 3, 6 and 9 WAS.

Sharma and Singh (1993) conducted an experiment with *Brassica juncea* cv. pusa Bold which was not irrigated, irrigated at the rosette stage (28-30 days after sowing), siliquae formation stage (55 DAS) or rosette stage siliquae formation stages. One irrigation at the rosette stage gave significantly higher yields compared with one irrigation at suiquae formation stage and unirrigated treatments.

Gill and Narang (1993) observed in an experiment with gobhi sarson that all growth parameters and seed yield significantly increased, while irrigation was applied at 20 days after sowing under cumulative pan evaporation of 80 mm.

Tomer *et al.* (1992) conducted an experiment to find out the effect of irrigation levels on the growth and yield of mustard (*Brassica juncea*). They worked with three irrigation treatments viz. no irrigation, one irrigation (at pre-flowering stage) and two irrigation (one at pre-flowering and another at fruiting stage). They concluded both levels of irrigation significantly increased the seed yield over no irrigation. Application of 2 irrigations (at pre-flowering and fruiting stage) out yielded one irrigation (pre-flowering stage).

Sharma, and Giri (1988) conducted an experiment in the rabi seasons of 1986-1987 on clay loam soil at Mandsaur, Madhya Pradesh of India and found that no irrigation, 1 irrigation at 15 or 30 days after sowing or 2 irrigations at 15 + 30 or 30 + 60 days after sowing gave mustard (*Brassica juncea*) cv. Varuna seed yields of 0.92, 1.05, 1.11, 1.28 and 1.47 t ha^{-1}, respectively, in 1986-1987 and 1.24, 1.46, 1.59 and 1.96 t ha^{-1} in 1987-1988.

Siag and Verma (1990) concluded that mustard (*Brassica juncea*) given 1irrigation at the vegetative, flowering or siliquae development stage, or 2 or 3 irrigations, gave average seed yields of 1.67, 1.78, 1.90, 1.95-1.98 and 2.14 t ha^{-1} respectively.

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

Tomer and Singh (1990) found that irrigating *Brassica juncea* cv. Varuna at flowering or flowering and fruiting stages or not irrigating, produced seed yields of 1.18, 1.45 and 0.83 t ha^{-1} respectively.

Sharma and Kumar (1989b) observed *Brassica juncea* cv. Krishna was unirrigated or given 1 irrigation at the rosette stage with or without irrigation at siliquae formation. Average seed yield ranged from 0.77 t ha^{-1} without irrigation to 1.37 t ha^{-1} with irrigation.

Rathore and Patel (1989) reported that mustard (*Brassica juncea*) gave highest yields with 3 irrigations at branching, 50% flowering and seed filling, followed by 2 irrigations at branching and 50% flowering, and irrigation at late branching.

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

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

Rathore and Patel (1989) reported that mustard (*Brassica juncea*) gave highest seed yields with 3 irrigations at branching, 50% flowering and seed filling, followed by 2 irrigations at branching and 50% flowering, and irrigation at late branching.

Sarkar *et al*. (1989) reported that mustard irrigated at flowering stage produced the highest seed yield and this was followed by the plants irrigated at vegetative and siliquae filling stages.

Sharma and Kumar (1988) irrigated mustard (*Brassica juncea*) with 60 cm water depth and cumulative pan evaporation ratio of 0.4 or 0.6 (one and two irrigations respectively) and reported the seed yields of 1.31 and 1.46 t ha^{-1} in 1984-1985 and 1.03 and 1.23 t ha^{-1} 1985-1986 respectively compared with respective yields of 0.82 and 0.71 t ha^{-1} rainfed conditions.

Mondal *et al*. (1988) conducted a field trials in the rabi (winter) seasons on *Brassica juncea* cv. T-59 was sown in the 1st week of November and given 1-4 irrigation treatments (1-4 irrigations at pre-flowering, flowering, early siliquae or late siliquae developmental stages). Maximum yields with 1 irrigation at flowering were 1.81 and 1.85 t ha^{-1} with 2 irrigations at flowering and late siliquae stages were 2.56 and 2.46 t ha^{-1}, and with 3 irrigations supplied at pre-flowering, early and late siliquae stages were 2.06 and 2.10 t ha^{-1}.

Hasan *et al*. (1988) conducted afield experiments in 1986-1987 at 2 locations in Bangladesh, mustard (*Brassica juncea*) was given no irrigation, 1 irrigation 20-25 DAS (I0 or I1 together with later irrigation when IW: CPE (irrigation water depth and cumulative potential evaporation ratio) reached at 0.2, 0.4, 0.6, or 1.0. Highest seed yield of 1.29 t ha^{-1} resulted from irrigation at 1 and 2 irrigations when IW: CPE was 0.4 at 1 location, whereas at the other location the highest seed yield of 1.18 t ha^{-1} resulted from irrigation at and 4 irrigations when IW : CPE was 1.0.

2.1.8 Oil content

Singh and Saran (1992) observed in an experiment with *Brassica campestris* during the winter seasons of 1987-1989 that irrigation at IW and CPE ratio of 0.4 and 0.2 (two and one irrigation, respectively) gave average oil content of 43.2 and 43.0% respectively compared to 43.3% from the control treatment. They observed that there was no significant effect of irrigation levels on oil content.

2.2 Effect of sulphur

Various authors demonstrated the yield response to different levels of sulphur application, which differ with genotypes and growing conditions. The number of seeds per siliqua contributes materially towards the final seed yield in rapeseed. So, the number of seeds siliqua^{-1} is an important yield-contributing attribute of rapeseed and mustard and sulphur rate is a vital factor in producing number of seeds siliqua^{-1}. The weight of 1000-seed expressed the magnitude of seed development that is an important yield determinant and plays a decisive role in showing the yield potential of a variety. Final seed yield per unit area of rapeseed is the cumulative effect of various yield components like number of siliqua per plant, number of seeds per siliqua, 1000- seed weight etc.

Chauhan and Bhargava (1984) observed that in rapeseed and mustard more than 90% of the total dry matter (TDM) was accumulated during the reproductive period and one third of TDM was partitioned into seed yield.

Raut *et al*. (1999) observed that S at 40 kg ha^{-1} resulted in the highest dry matter production at 30 (1.22 g per plant), 60 (31.86 g per plant), and 90 DAS (72.55 g per plant) and at harvest (100.7 g per plant). The highest grain yields (16.24 and 16.22 q ha^{-1}) were obtained with 40 and 60 kg S ha^{-1}. Sulphur has been reported to influence productivity of oil seed (Singh *et al*., 1999). Similarly, Biswas *et al*. (1995) reported that application of S fertilizer increased the seed yield of mustard.

Chaubey *et al*. (2001) reported that number of branches/plant and yield attributes (Siliquae/plant, length of siliqua, seed/siliqua and 1000-seed weight) increases significantly with the increasing level of S upto 30 kg S ha^{-1}.

Davaria et al. (2001) reported that S had no significant effect on growth and yield, except for seed yield, which was highest at 50 and 100 kg ha^{-1} (13.28 and 14.12 q ha^{-1}, respectively).

Prakash and Sing (2002) found that seed yield, protein and oil content and oil yield increased with the increase in sulphur rate up to 40kg ha^{-1} only.

Sudhakar *et al*. (2002) observed that S significantly improved plant height, number of primary and secondary branches per plant, number of siliquae per plant, number of seeds per siliquae, test weight, seed yield and stover yield. The increase in these parameters was observed up to 60 kg S ha^{-1} increase in plant height with an increase in rate of sulphur aoolication has also been reported by a number of workers (Khanpara *et al*., 1993; Tomer *et al*. 1997; Rana *et al*.; 2001).

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

Abdin *et al*. (2003) conducted a field experiment and it was conclude from his experiment that the yield and quality of rapeseed-mustard could be optimized with the application of 40 kg S ha^{-1}.

Sana *et al*. (2003) reported the final plant height reflects the growth behavior of a crop. Besides genetic characteristics environmental factors also play vital role in determining the height of the plants.

Mandal and Sinha (2004) reported that dry matter production and significantly increased with increasing level of sulphur up to 20 kg S ha^{-1} and LAI up to 40 kg S ha^{-1}.

Misra (2003) conducted a field experiment and showed that mustard crop significantly to theapplication of S. The seed and stover yields increased in the linear order up to 40 kg S ha^{-1}. The highest seed yield (2035 kg ha^{-1}) at 40 kg S ha^{-1} was 27.59% higher in comparison to the yield at control.

Prasad *et al*. (2003) found that S at 20 kg S ha^{-1} produced the highest growth, yield and productivity.

Subhani *et al*. (2003) found that application of different S fertilizers (10-50 kg S ha^{-1}) significantly increased the seed yield of rapeseed and mustard crops ranging from 5.2- 76.7% as compared to control.

Alam (2004) reported that plant height of rapeseed and mustard differ among the varieties depending on their genetic makeup. There are three species of cruciferous *Brassica* viz. *Brassica campestris*, *Brassica juncea* and *Brassica napas* every one of which differs from another with respect to plant growth, development and yield.

Nepalia (2005) reported that application of S up to 60 kg ha^{-1} significantly increased crop dry matter, leaf area index and productivity of mustard.

Sah *et al*. (2005) reported that the yield attributes and yield increased significantly with the increasing levels of S up to 40 kg ha^{-1}.

Sharma *et al*. (2005) reported that S application significantly increased the number of primary branches, number of siliquae per plant, length of siliquae and 1000-seed weight. Optimum seed yield (14.9 quintal ha^{-1}) was obtained with the application 0f 65.0 kg S ha^{-1}. S application also increased the stover and total dry matter yields.

Duhan *et al*. (2006) reported that application of S significantly increase the grain and straw yield of two cultivars of raya at all the levels of sulphur application. Number of pods per plant and oil content in raya seed were increased with the increasing levels of S in both the cultivars. Application of sulphur also increased the uptake of nitrogen, phosphorus, potassium and sulphur by raya in both the cultivars. Regarding two cultivars Luxmi recorded the higher grain and straw yields and oil contents in grain over RH-30 but cultivar RH-30 recorded the higher number of pods per plant over the cultivar Luxmi.

Kumar *et al*. (2006) observed that Indian mustard responded significantly to the application of S. The seed and stover yields increased linearly up to 40 kg S ha^{-1}. Application of 40 kg S ha^{-1} gave the highest seed yield (18.37 g ha^{-1}), which was 28.1% more in comparison to that of the control.

Piri and Sharma (2006) reported that yield attributes, seed and straw yields, oil content and oil yield and sulphur content and uptake in both seed and straw increased significantly with increasing level of sulphur up to 45 kg S ha^{-1}. S at 15, 30 and 45 kg ha^{-1} increased seed yield over the control by 9, 16 and 23%.

Jat and Mehra (2007) reported increase in growth and yield attributes with increasing levels of sulphur for its role in synthesis of protein, oil and vitamins.

Kumar and Yadav (2007) reported that a significant response of crop was observed up to 30 kg S/ha in seed and stover yields.

Mehdi and Singh (2007) reported that sulphur fertilization significantly increased the growth attributes, i.e. plant height, dry matter, leaf area index, relative growth rate at initial vegetative growth stage, primary and secondary branches. Marked improvement was also observed in all yield contributing characters, i.e. 1000-seed weight, seed weight per plant, number of siliquae per plant, siliquae length, seed and straw yield as a result of application up to 40 kg/ha. Thus to obtain higher growth and seed yield of Indian mustard under subtropical western tract of Uttar Pradesh, application 40 kg S ha^{-1} together with recommended doses of other major nutrients was found to be most appropriate fertilizer combination.

Singh *et al*. (2007) conducted a field experiment in India, during the 2003/04 winter season and showed that the growth, yield attributes and seed including stover yields of Indian mustard showed a linear increase with an increase in levels of S up to 45 kg ha^{-1}.

Singh *et al*. (2008) conducted a field experiment and six yield components were evaluated i. e. final plant height, number of functional leaves plant^{-1}, siliquae plant^{-1}, seed yield, dry matter content and stove yield. A linear increase in all the traits was observed up to 45 kg S ha^{-1}. Results obtained under 15 kg S ha^{-1} was non-significantly higher than those under 30 kg S ha^{-1}.

Khalid *et al*.(2009) reported that 40 kg S ha^{-1} produced highest biomass (9058 kg ha^{-1}), seed yield (1656 kg ha^{-1}) and plant S content (0.158 g 100g), but these increases were statistically at par with that of 30 kg S ha^{-1}. Rapeseed yield was significantly influenced by S application. The maximum biomass (9292 kg ha^{-1}) and seed yield (1843 kg ha^{-1}) were recorded. The application of 40 kg S ha^{-1} produced higher biomass (9058 kg ha^{-1}) and seed yield (1656 kg ha^{-1}) but these were statistically at per with 30 kg S ha^{-1}.

Dabhi *et al*. (2010) found that maximum growth, yield attributes and uptake of S with 40 kg S ha^{-1} ultimately resulted in the highest seed yield of mustard which was higher by 15.35% over control.

Singh *et al*. (2010) observed that the highest seed yield (2035 kg/ha) at 40 kg S/ha was 27.59% higher in comparison to the yield at control. Yield and yield attributes of brown sarson increase significantly with increase rates of S up to 40 kg S/ha. However, the difference between 40 and 60 kg S ha^{-1} for growth and yield attributes were non-significant. Increase in siliquae $plant^{-1}$, seeds $siliquae^{-1}$, test weight, seed and stover yield was to the tune of 14.2, 22.4, 15.3, 27.6 and 37.63% respectively with 40 kg S ha^{-1} over control.

Bharose *et al*. (2011) reported that application of varying doses of S had significant effect on the yield of toria. The seed yield inceased from 11.80 to15.89 q ha^{-1} progressively with increase in level of S from 0.00 to 20.00 kg ha^{-1} and yield decreases with the application of higher doses of S (40.00kg ha^{-1}). The result is in conformity with the findings of Singh *et al*. (1997), Tomer *et al*. (1996).

Kumar *et al*. (2001) conducted a field experiment and observed that among the sulphur level, 45 kg ha^{-1} being at part with 30 kg ha^{-1}gave significantly higher seed yield (1.18 and 1.26 t ha^{-1}).

Piri *et al*. (2011) conducted a field experiment in two years and observed that plant height increased with increasing level of S at all growth stages in both the years. However the difference between 0 and 15 kg S ha^{-1} at 90 DAS in both the years and at harvest in second year, 15 and 30 kg ha^{-1} at 90 DAS and at harvest in first year and at 45 DAS in second year and between 30 and 45kg S/ha at 45 DAS in second year and between 15 and 30 kg S/ha at 90 DAS in first year and at harvest in both the years were not significant. The increase in plant height with the application of sulphur is attributed to increased metabolic processes in plants with sulphur application which seems to have promoted meristemetic activities resulting in higher apical growth and expansion of photosynthetic surface. Increase in plant height with an increasing rate of S application has also been reported by a number of workers (Khanpara *et al*., 1993; Tomar *et al*.; 1997; Rana *et al*., 2001).

Verma *et al*. (2012) observed that application of 60 kg S ha^{-1} gave significant higher plant height, number of functional leaves $plant^{-1}$, number of primary and secondary branches $plant^{-1}$, dry matter production $plant^{-1}$, number of siliquae $plant^{-1}$, number of seed $siliquae^{-1}$, 1000-seeds weight, seed yield. Among S level application of 60 kg S ha^{-1} gave significantly higher seed yield (20.98 kg ha^{-1}) than control, 20 and 40 kg S/ha owing to better expression of siliquae length, number of siliquae $plant^{-1}$, number of seed $siliquae^{-1}$, 1000-seeds weight, harvest index and seed yield. The other growth parameters such as plant height, number of functional leaves $plant^{-1}$, number of primary and secondary branches $plant^{-1}$, dry matter production $plant^{-1}$ showed similar trend. Application of 60kg S ha^{-1} recorded significantly higher growth parameters and seed yield and yield attributes than control, 20 and 40 kg ha^{-1}, which may be due to better growth and development. These results are in close conformity to those of Patel *et al*. (2010), Hussain and Thamos (2010), Sharma (2008). The highest seed yield of 21.70 q ha^{-1} was observed with the application of 60 kg S ha^{-1}.

Ali and Taman (1997) reported that an increase in S application progressively increased the N and S uptake at 40 and 70 days after sowing and at harvest. S application at 10-30 kg ha^{-1} gave 8.5, 14.0 and 22.3% more seed yield than controlled.

Bikram *et al*. (1999) reported that application of 45 kg S ha^{-1} increased the oil content in *Brassica juncea*.

Sawarkar *et al*. (1987) found that increasing the rates of applied S from 0 to 60 kg ha^{-1} increased the average oil content in mustard from 40.46 to 45.05% but decreased average protein content from 18 .84 to 17.48%, and S contents from 0.28% to 0.26%.

2.3 Interaction effect of irrigation and sulphur

Piri and Sharma (2007) reported that both irrigation and sulphur significantly increased the yield attributes and seed and straw yields of Indian mustard. The crop responded to S differentially under different irrigation regimes. Without irrigation, the seed yield of Indian mustard increased when the S level increased from 0 to 45 kg S ha^{-1}, whereas with 1 or 2 irrigations; the seed yield increased with 30 kg S ha^{-1}.

A field experiment was conducted by Ghadge *et al.* (2005) to study the effect of irrigation, phosphorus and sulfur on the uptake and availability of sulfur (S), nitrogen (N) and phosphorus (P) in Akola, Maharashtra, India, during the 2001/02 rabi season. Five irrigations applied at pre-sowing and at 0.60 IW: CPE ratio recorded the highest S, P and N content in the seed and straw. After harvest, the S, N and P contents in the soil were highest with 3 irrigations applied at pre-sowing and at the flowering and grain filling stages (55 and 70 days after sowing, respectively).

Bharati and Prasad (2003) observed that yield contributing characteristics and yield are significantly affected by different levels of irrigation. But seed yield, 1000-seed weight and net returns did not significantly vary with the S rate. The application of 45 kg S per ha resulted in the highest oil content (41.84%) and oil yield (0.63 t ha^{-1}). The highest dry matter production was found by S uptake for 15 and 30 kg S per ha with two irrigation.

Bharati and Prasad (2001) investigated that there was a significant effect irrigation and of sulphur rate on growth and yield attributes as well as on yields of rai but significant increase was only up to two irrigation and 15 kg S ha^{-1} over control treatments, respectively. This was statistically at par with 30 and 45 kg S ha^{-1}. Higher values of seed and stalk yields were recorded at higher doses but it could not show superiority over 15 kg S ha^{-1} (13.59 q seed and 61.33 q stalk ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from 12th November 2013 to 8th February 2014. Details of different materials used and methodology followed for conducting this experiment have been presented in this chapter.

3.1 Site and soil

The experiment was laid out in the non calcarious dark brown floodplain soil of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The site of the experimental plot is in the 23°74 N latitude and 90°35 E longitudes with an elevation of 8.2m above flood level.This soil belongs to the Modhupur tract under Agro-Ecolological Zone 28 (AEZ-28) was presented in Appendix-I.

3.2 Climate

The experimental area has subtropical climate characterized by heavy rainfall during May to September and scantly rainfall during rest of the year. The annual precipitation of the site is 2152 mm and potential evapotranspiration is 1297 mm, the average maximum temperature is 30.3^{o} C and average minimum temperature is 21^{o} C. The average mean temperature is 25.8^{o} C. The experiment was carried out during rabi season, 2013-14. Temperature during the cropping period ranged from 20^{o} C to 29.2^{o} C. The humidity varied from 61.72% to 70.45%. The day length was reduced to 10.5-11.0 hours only and there was no rainfall from the beginning of the experiment to harvesting. The monthly average temperature, humidity and rainfall of the site during the experimental work are enclosed in appendix II.

3.3 Variety used

The variety SAU SR-12 is a high yielding line (F_{12} progeny of SS-75 X Tory-7) under brown sarson group of *Brassica campestris* developed by Professor Dr. Md. Shahidur Rashid Bhuiyan, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University was used for the experiment. Before sowing, germination test was carried out in the laboratory and percentage of germination was found to be over 90%.

3.4 Layout of the experiment

The experiment was laid in a Split Plot Design with three replications to reduce the heterogenetic effect of soil. Irrigation treatments were applied in main plot and sulphur treatments in sub plot. So each replication was divided into 3 unit plots and each plot was divided into three sub-plots as treatments. Thus the total number of main plots was 9(3x3) and subplot was 27(9x3). The unit subplot size was $6m^2$ (4.0 m x 1.5 m). The distance between the blocks was 1.0 m. The distance among the main plots was 1m and among the subplots 0.5m. Allocation of all the treatments was made at random in each block.

3.5 Irrigation treatments under investigation

There were three irrigation treatments in the experiment. They were

I_1= no irrigation (control)

I_2= once irrigation at 53 DAS

I_3= twice irrigation at 25 DAS and 53 DAS

Irrigations were given as per treatments. First irrigation was given at 07 December 2013 (25 DAS) in the plots according to the treatments. The second irrigation was given at 8 February 2014 (53 DAS) in the plots as required by the treatments. After first irrigation at joe condition all the plots were spaded uniformly and carefully to conserve the moisture.

3.6 Fertilizer treatments under investigation

There were three sulphur fertilizer treatments in the experiment. The standard rate of fertilizer applied was N @ 82 kg ha^{-1}; P_2O_5 @ 82 kg ha^{-1}; K_2O @ 60 kg ha^{-1}, Boric acid @10 kg ha^{-1}. There were three level of sulphur:

S_1= 15 kg S ha^{-1}

S_2= 30 S kg ha^{-1}

S_3= 45 kg S ha^{-1}

3.7 Land preparation

The land was first ploughed with a tractor drawn disc plough on 30 October 2013. Ploughed soil was brought into desirable tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The land operation was completed on 12 November 2013. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.8 Application of fertilizers

Fertilizers were used as urea, TSP, MOP, gypsum and boric acid for N, P, K, S and B respectively. The total required amounts of P, K, S, B and 50% N were applied plot wise as per treatments after final land preparation and layout of the experiment and were mixed with the soil through hand spading. The rest of the N (urea) was applied as top dressing after 25 days of germination and just before flowering. The required amount of sulphur (Gypsum) as per treatment was applied uniformly in the subplots.

3.9 Sowing of seeds

The seeds of SAU SR12 at the rate of 8 kg ha^{-1} were sown in rows by hand. The distance of row to row was 30 cm. After sowing, the seeds were covered with soil and slightly pressed by hand. The seeds were sown on 12th November 2013. Sowing was done at suitable condition of soils, which ensured satisfactory germination of seeds. First germination date was recorded after 4 days of sowing.

3.10 Intercultural Operation

The following intercultural operations were done for ensuring and maintaining the normal growth of the crop.

3.10.1 Irrigation

According to treaatments irrigations were given once on 7^{th} December 2013 and 4^{th} January 2014, respectively after 25 days and 53 days of sowing in order to maintain enough moisture in the field. There was scanty rainfall in the period of cultivation of the crop.

3.10.2 Weeding and thinning

Two weeding and thinning were done at 12 and 25 days after germination. Thinning was done in all unit plots carefully to maintain a uniform plant population per plot.

3.10.3 Insect and pest control

The crop was found infested with aphids *(Lipaphis ersimi)* at the time of siliqua filling. The insects were controlled successfully by Marshal 30 @ 1m1 L^{-1}. The insecticide was sprayed on 5th February 2014. The crop was kept under constant observations from sowing to harvesting.

3.11 Sample collection, harvesting and threshing

The crop maturity varied with fertilizer treatments, when around 80% of the siliquae in terminal raceme turned golden yellow in color then crops were harvested. Collection of sample was done as per requirement. Samples were collected randomly i.e. from different places of each plot leaving undisturbed one meter square in the centre. After collection of the sample, harvesting and threshing were done. The harvested crops were tied into bundles and carried to the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.12 Collection of experimental data

For the convenience of collecting data, ten plants per plot were selected at random and were tagged for the data collection. Data were collected at maturity stage and post-harvest stage. The sample plants were uprooted prior to harvest and dried properly in the sun before collecting data. The seeds and straw yield per plot were recorded after cleaning and drying them properly in the sun.

The procedures followed to collect the data for different characters are given below:

3.12.1 Plant height

The height of 10 plants of each plots were measured from the ground level to the tip of the topmost siliquae and average was taken and expressed in centimeter (cm).

3.12.2 Number of branches per plant

The number of branches was counted and recorded. The primary branches were counted from the ten tagged plants in each plot at harvest and average was taken. The ten tagged plants in each plot were also used for counting the number of secondary branches at harvest.

3.3.12.3 Number of siliquae per plant

The number of siliquae from ten tagged plants were counted after the harvest and expressed on per plant basis.

3.12.4 Length of siliquae

Ten siliquae were randomly selected from the five plants and the average length of siliquae was calculated.

3.12.5 Number of seeds per siliquae

Ten siliquae were randomly taken from all siliquae of each plot and the seeds were counted. The average number of seeds per siliquae was determined.

3.12.6 Seed yield per plant

The separated seeds of ten plants were collected, cleaned, dried and weighed properly. The average seed yield per plant was then recorded in gram.

3.12.7 Seed yield

The seed weights were taken by threshing the harvested plants of each plot and converted the yield to t ha^{-1}.

3.13 Oil content of seed

Oil content of seed was determined by Soxhlet method and expressed in percentage (%). For this purpose 25 g clean seed sample was used. This was done in Oil Seed Research Centre, BARI, Joydebpur, Gazipur-1701.

3.14 Preparation of plant samples for analysis

The collected plant sample from each plot was dried in an oven at 60°C for about 48 hours and then ground to pass through a 20 mesh in a grinding mill. The prepared samples (straw) were then put into paper bags and kept in a desiccator before analysis.

3.15 Plant sample analysis for the estimation of mineral constituents

Preparation of plant extract by diacid mixture method

Exactly 1 g of each plant sample was placed in 250 mL conical flask. 10 mL of diacid mixture (concentrated nitric acid: 60% perchloric acid = 2:1) was added to each conical flask. The flask was then placed on an electrical hot plate and heated gradually to 180^{o}C. The temperature was raised to 220^{o}C after 30 minutes. When white fumes of perchloric acid were observed, the flasks were removed from the hot plate and were allowed to cool. The volume of digest was then made up to 30-40 ml with distilled water. Then the digest was filtered through Whatman No. 42 filter paper and volume to 100 ml with distilled water.

3.16.1 Sulphur

Sulphur content of plant extract was determined by turbidometric method with the help of a spectrophotometer, set at 420 nm (Wolf, 1982).

3.16.2. Phosphorus

The phosphorus of the plant sample (diacid mixture extract) was determined colorimetrically by ascorbic acid blue colour method. The absorbance was recorded at 660 nm (Olsen *et al.* 1954).

3.16.3 Potassium

Potassium of the plant sample (diacid mixture extract) was determined with the help of the flame emission spectrophotometer. The samples were aspirated into a gas flame. The air pressure was fixed at 10 psi. percent emission was recorded following the method described by Ghosh *et al.* (1983).

3.16.4 Total nitrogen estimation from grain

The total nitrogen of each sample was estimated by the Macro kjeldahl method through the digestion of organic matter by concentrated sulphuric acid (H_2SO_4) which was then mixed with sodium hydroxide (NaOH) for distillation. The distilled ammonia was received in boric acid (H_3BO_3). Then mixed indicator solution bromocressol green ($C_{21}H_{14}Br_4O_5S$) and methyl red ($C_{15}H_{15}N_3O_2$) was added and was titrated against a standard H_2SO_4 until the end point appeared from green to pink (PCARR, 1980). The amount of N was calculated by using the following formula:

$$\% N = (T-B) \times N \times 1.4 / S$$

Where, T = Sample titration mL standard H_2SO_4

B= Blank titration mL standard H_2SO_4

N = Normality of H_2SO_4

S = Sample weight in gram.

3.17 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the F (variance ratio) test. The significance of the differences among means was estimated by Least Significant Difference Test (LSD) at 5%.

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of different levels of irrigation and sulphur on yield and yield contributing characters of rapeseed. The analyses of variance (ANOVA) of the data on different components are given in Appendix III-VII. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Plant height

4.1.1 Effects of irrigation on plant height

Significant variation was found due to the effect of irrigations in plant height of rapeseed (Figure 1). The highest plant height (95.97 cm) at harvest was found from the treatment I_3 (Two irrigations), which was significantly different from the other treatments. The lowest plant height (66.18 cm) was found from the control treatment (no irrigation) throughout the life cycle. Siag *et al.* (1993) reported maximum plant height was found when irrigation was applied during branching and siliquae development stage.

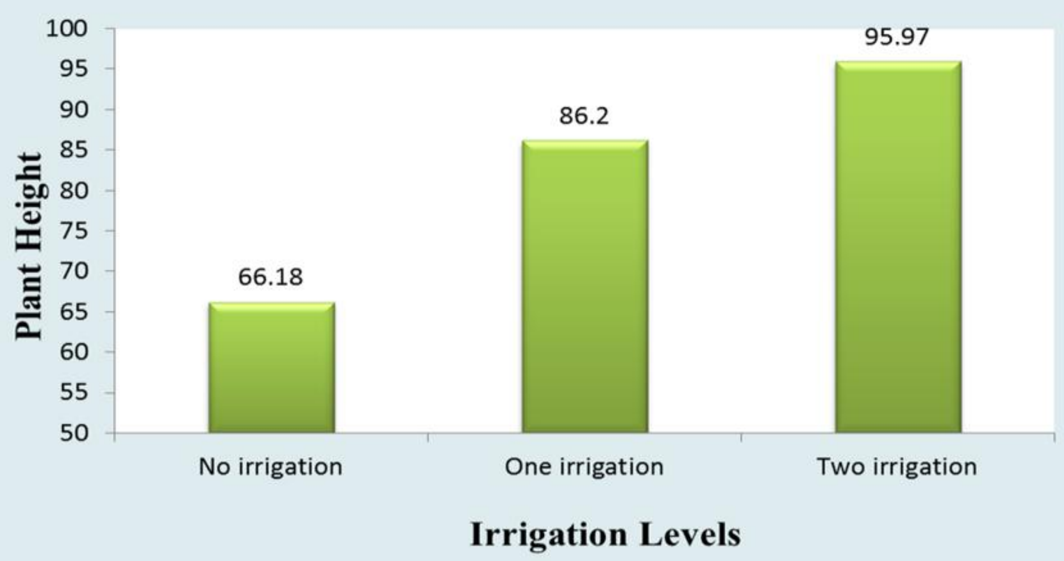

Figure 1. Effect of different levels of irrigation on plant height

4.1.2 Effect of sulphur on plant height

Plant height was significantly affected by sulphur fertilization (figure 2). The plant height increased progressively with the application of increasing levels of sulphur. Highest plant height (83.08 cm) was recorded with the application of 45 kg S ha^{-1}. The lowest plant height (82.37 cm) was observed 15 kg S fertilizer application. The maximum plant height at harvest (96.40 cm) was obtained from the treatment S_3 which was statistically similar with S_2. Singh and Saran (1998); Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased the plant height of mustard over no sulphur application. Piri and Sharma (2006) found that plant height was increased significantly up to 45 kg S ha^{-1} application.

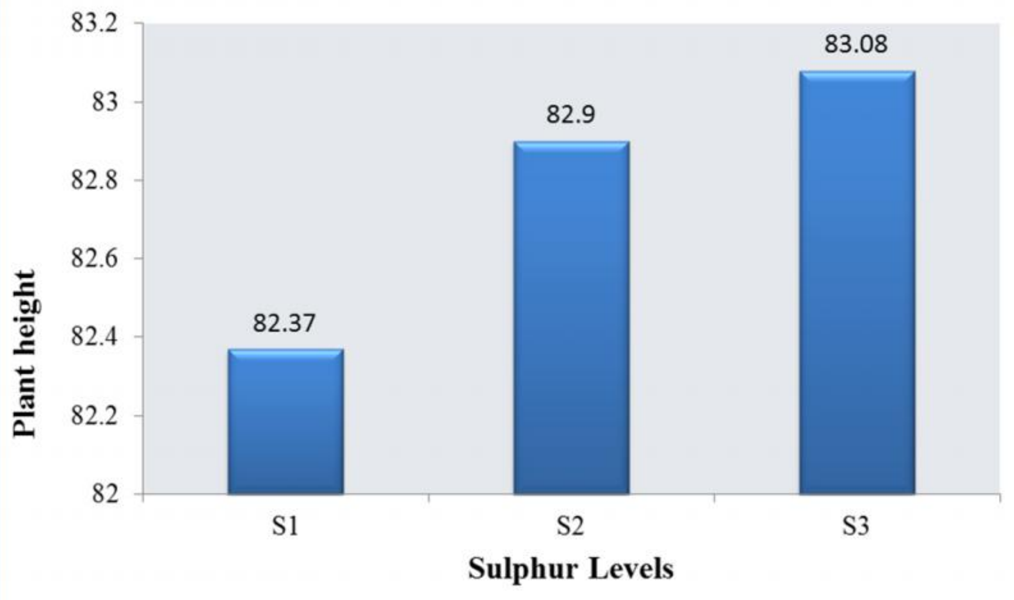

Figure 2. Effect of different sulphur levels on plant height

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1} and S_3 = 45 kg Sulphur ha^{-1}

4.1.3 Interaction effect of irrigation and sulphur

The interaction effect of irrigation and sulphur had remarkable effect on the plant height of rapeseed (Figure 3). Significant differences of plant height were found a harvest. Maximum plant height (96.40 cm) was observed in the treatment I_2S_3 (two irrigations and 45 kg S ha^{-1}) which was statistically similar I_2S_2. The lowest plant height (66.33 cm) was found from the treatment l_0S_1. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that all yield contributing characters and yield of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

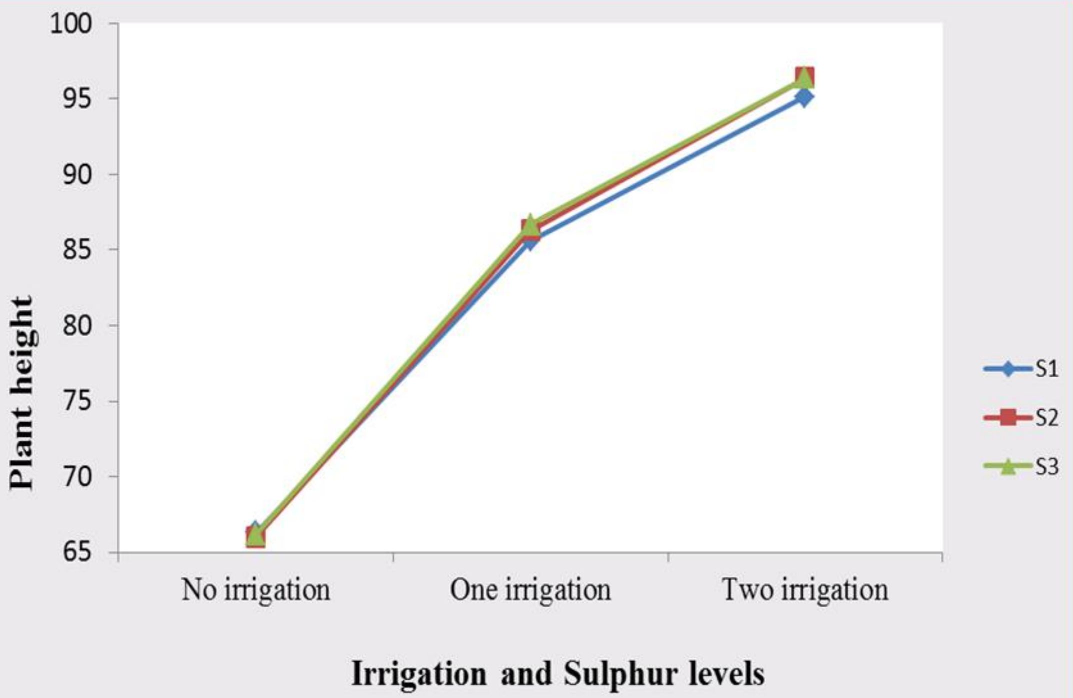

Figure 3. Interaction effect of irrigation and sulphur on plant height

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.2 Primary branches per plant

4.2.1 Effect of irrigation

From the study, irrigation had great influence on the number of primary branches per plant in mustard (Figure 3). Number of irrigation significantly increased the number of primary branches per plant. The maximum numbers of primary branches (7.064) were found from a plant subjected to two irrigations. The lowest numbers of primary branches (3.271) were found from control treatment. Tomer *et al.* (1992) noticed significant increase in the number of primary branches per plant up to two irrigations. Probably irrigation water supported plant to initiate more branches.

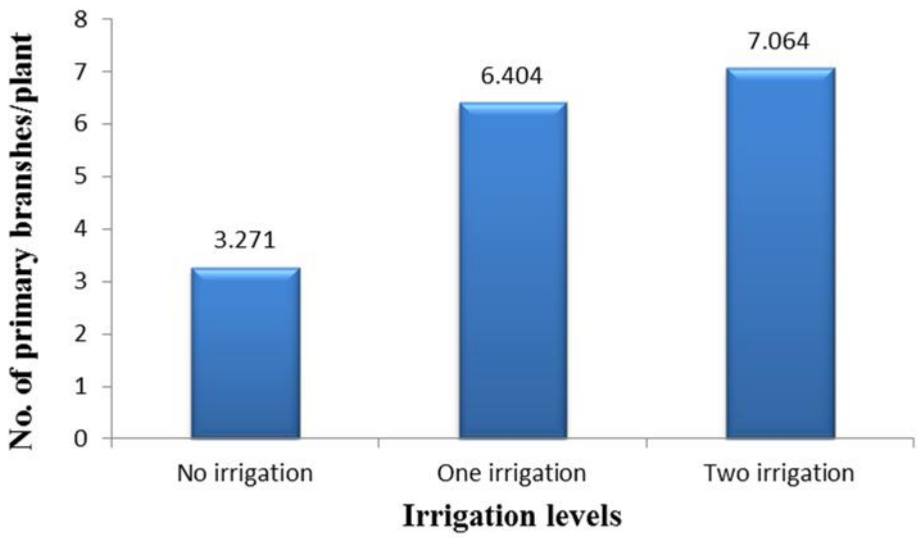

Figure 4. Efffect of irrigation on number of primary branches per plant

4.2.2 Effect of sulphur on primary branches

The effect of different levels of sulphur fertilizer was significant as observed on number of primary branches plant and the number of primary branch plant^{-1} is showed in (Figure 5). The maximum number of primary branches plant^{-1} (5.724) was produced with the application of 45 kg S ha^{-1} that was similar with 30 kg S ha^{-1}. The lowest number of primary branches plant^{-1} was recorded (5.363) in 15 kg S application. Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased the number of primary branches of mustard over no sulphur application but Piri and Sharma (2007) found that number of primary branches was increased significantly up to 45 kg S ha^{-1} application.

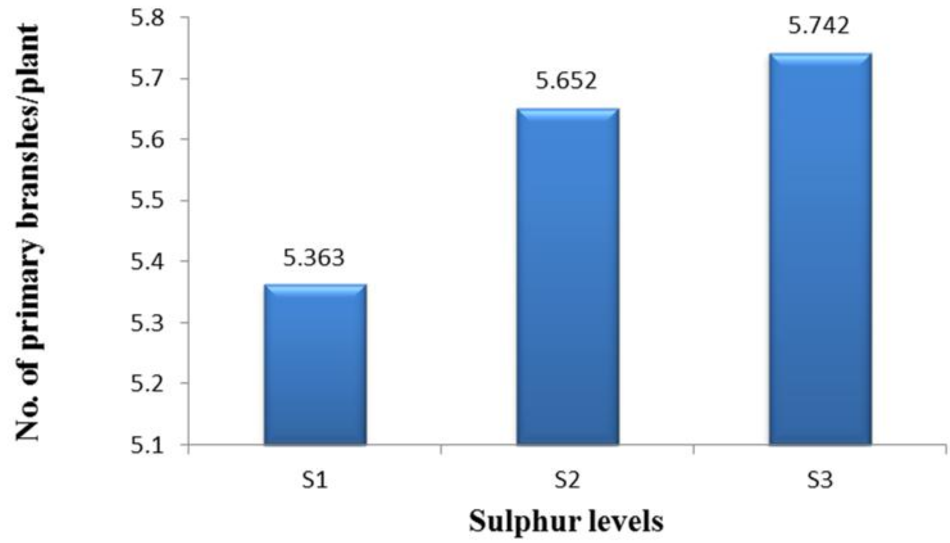

Figure 5. Efffect of sulphur on number of primary branches per plant

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1} and S_3 = 45 kg Sulphur ha^{-1}

4.2.3 Interaction effect of irrigation and sulphur

The treatment combination of irrigation and sulphur has significant effect on primary branches per plant (Figure 6). In the present work, it might be concluded that two irrigations and 45 kg S ha^{-1} produced maximum number of primary branches per plant (6.56) and the lowest number of primary branches per plant (3.237) were produced from the treatment I_0S_1. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that all yield contributing characters and yield of mustard increased significantly when two irrigations with 45 kg S ha^{-1} was applied.

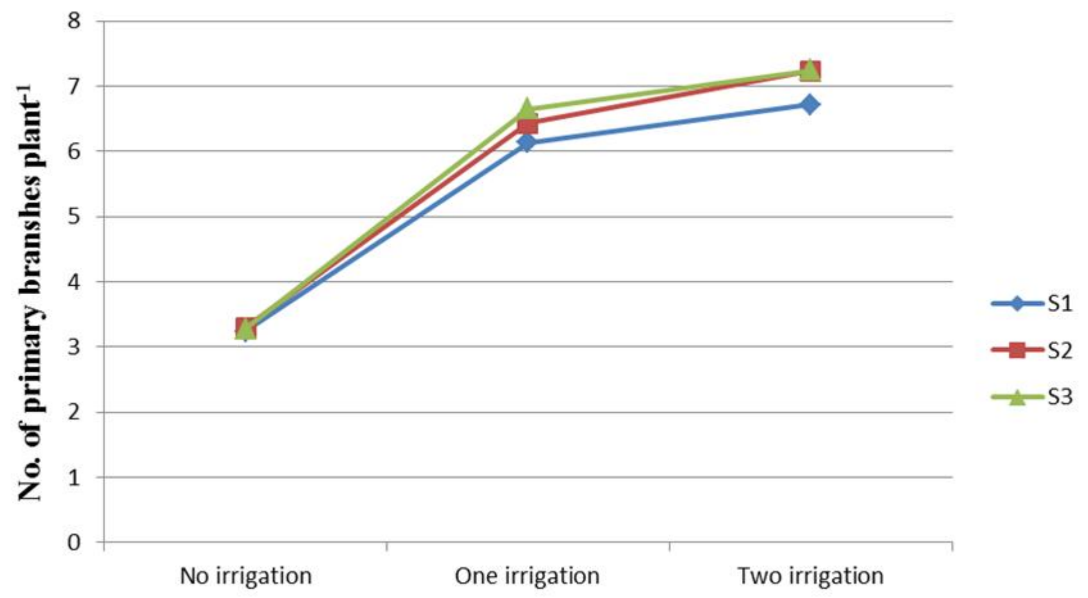

Figure 6. Inreraction efffect of irrrigation and sulphur on number of primary branches plant^{-1}

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1} and S_3 = 45 kg Sulphur ha^{-1}

4.3. Number of secondary branches per plant

4.3.1 Effect irrigation on secondary branches per plant

From the study, it was found that irrigation had great influence on the number of secondary branches per plant in mustard (Figure 7). Number of irrigation significantly increased the number of secondary branches per plant. The maximum numbers of secondary branches (8.754) were found from the plant subjected to two irrigations. The lowest numbers of secondary branches (3.319) were found from control treatment. Tomer *et al.* (1992) also reported that two irrigations gave the highest secondary branches per plant and the lowest number of secondary branches per plant was found in case of without irrigation.

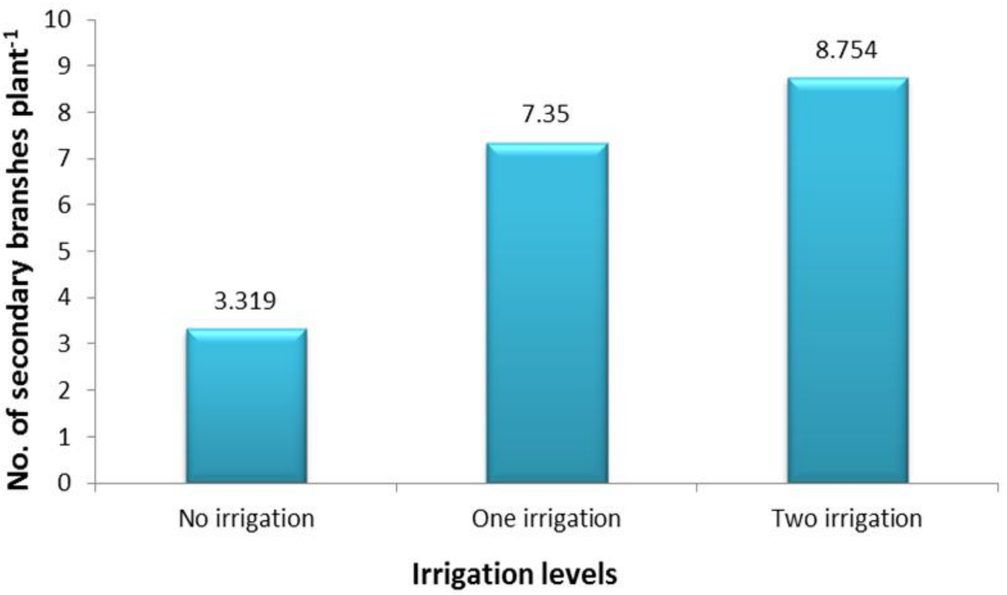

Figure 7. Efffect of irrrigation on number of secondary branches plant^{-1}

4.3.2 Effect of Sulphur

The effect of different levels of sulphur fertilizer was significant as observed on number of secondary branches plant^{-1} showed in (Figure 8). The maximum number of secondary branches plant^{-1}(6.608) was produced with the application of 45 kg S ha^{-1} that was similar with 30 kg S ha^{-1}. The lowest number of secondary branches plant^{-1} was recorded (6.287) in 15 kg S application. Piri and Sharma (2007) found that number of primary branches was increased significantly up to 45 kg S ha^{-1} application. Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased the number of secondary branches of mustard over no sulphur application.

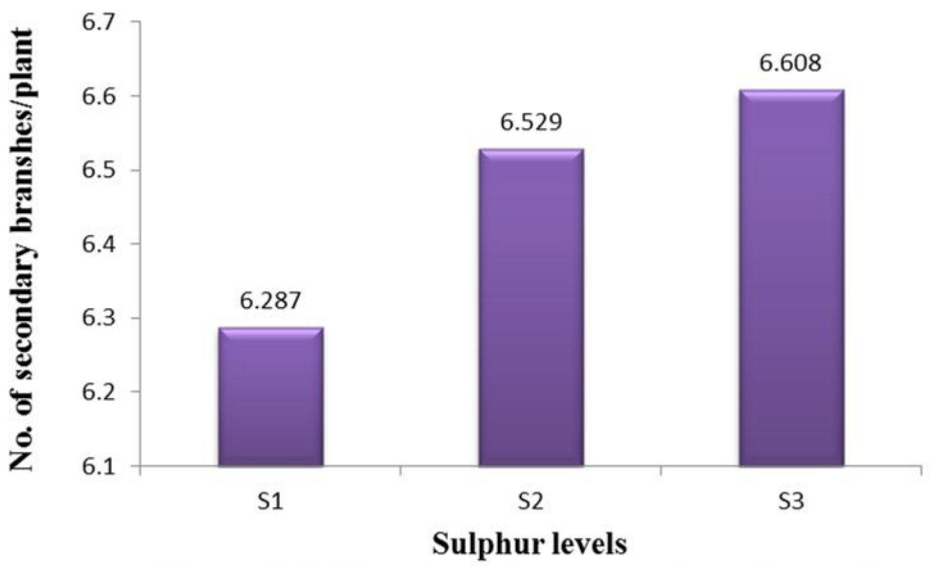

Figure 8. Efffect of sulphur on number of secondary branches per plant

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.3.3 Interaction effect of irrigation and sulphur

The treatment combination of irrigation and sulphur has significant effect on secondary branches per plant (Figure 9). In the present work, it might be concluded that two irrigations and 45 kg S ha^{-1} produced maximum number of secondary branches per plant (8.93) and the lowest number of secondary branches per plant (3.31) were produced from the treatment I_0S_1. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that all yield contributing characters and yield of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

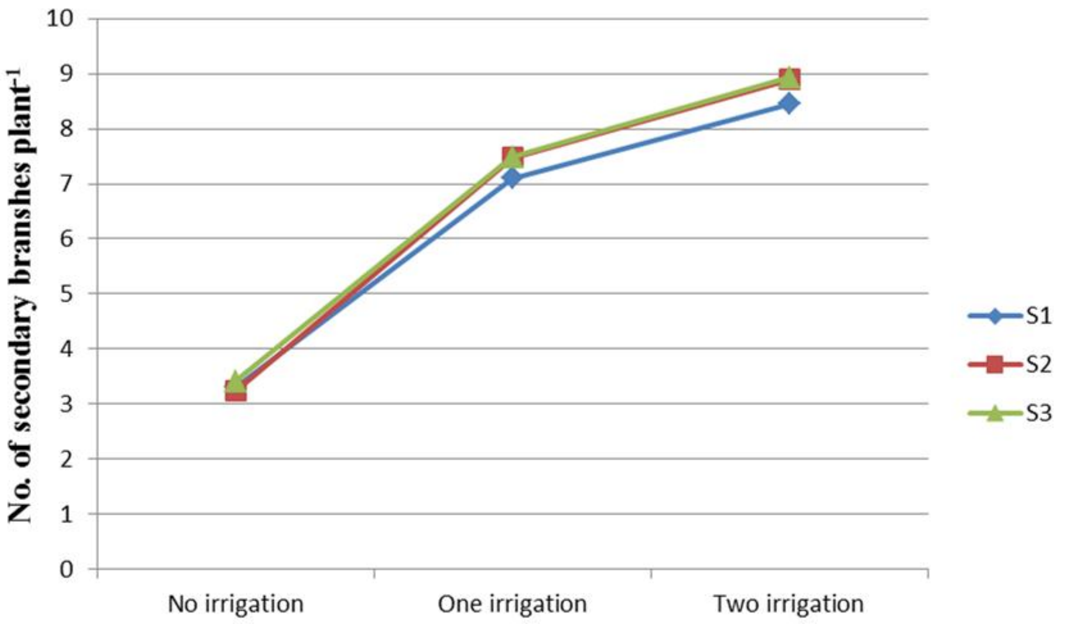

Figure 9. Inreraction efffect of irrrigation and sulphur on number of secondary branches plant^{-1}

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.4 Number siliquae per plant

4.4.1 Effects of irrigation on number siliquae per plant

Number of siliquae is an important factor for increasing yield, which is adversely affected by the soil moisture. Number of siliquae per plant was increased with the increasing levels of irrigations. In the present study, number of irrigation showed significant variation in producing siliquae per plant (Figure 10). Among the treatment I_3 produced the highest number of siliquae (147.3) per plant. The treatment Io (control) which was received no irrigation throughout the life cycle thus produced the lowest number of siliquae 54.02) per plant. Giri (2001) concluded that number of siliquae in the main inflorescence was increased up to two irrigations at pre-flowering and fruiting stage.

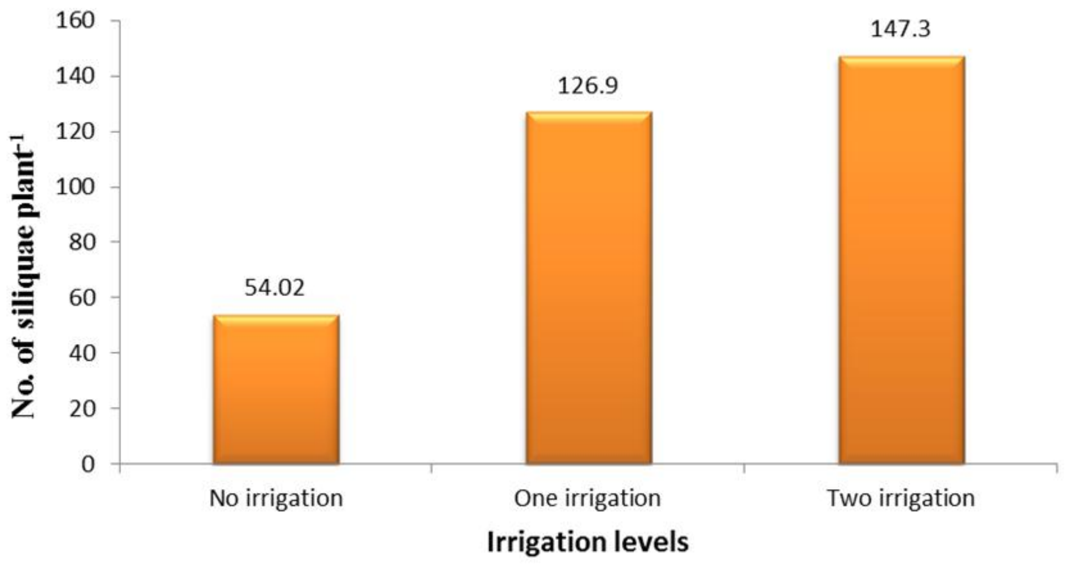

Figure 10. Efffect of different levels of irrrigation on number of siliquae plant^{-1}

4.4.2 Effect of Sulphur

Sulphur application increased the number of siliquae plant^{-1} significantly (Figure 11). The number of siliquae plant^{-1} varied from 107 to 111.3 at different treatment levels. The highest number of pods plant^{-1} (111.3) was obtained with application of 45 kg S ha^{-1}. The lowest (107) was in 15 kg S ha^{-1}. Piri and Sharma (2007) found that number of siliquae plant^{-1} was increased significantly up to 45 kg S ha^{-1} application but Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased the number of siliquae plant^{-1} of mustard over no sulphur application.

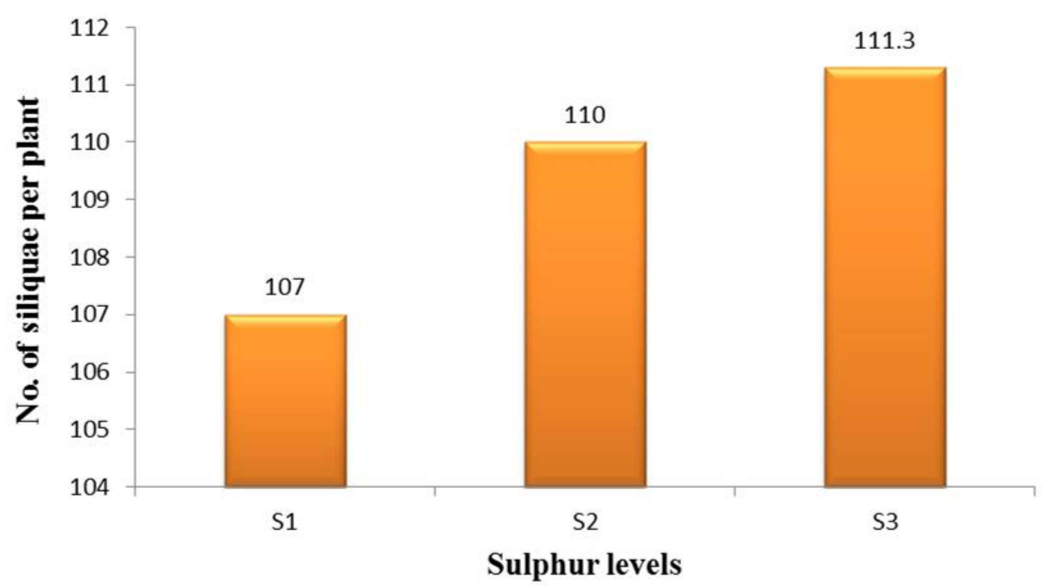

Figure 11. Efffect of different levels of sulphur on number of siliquae per plant

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.4.3 Interaction effect of irrigation and sulphur

From the study, it was also observed that treatment combination of irrigation and sulphur had significant effect on number of siliquae plant^{-1} (Figure 12) Two levels of irrigation with 45 kg S ha^{-1} produced maximum number of siliquae plant^{-1} (149.5) which was statistically similar with treatment combination of I_2S_3. Minimum numbers of siliquae plant^{-1} (54.12) was found in I_0S_2 treatment. Piri and Sharma (2007) reported the same result. On the hand Bharati and prasad (2003) observed that all yield contributing characters and yield of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

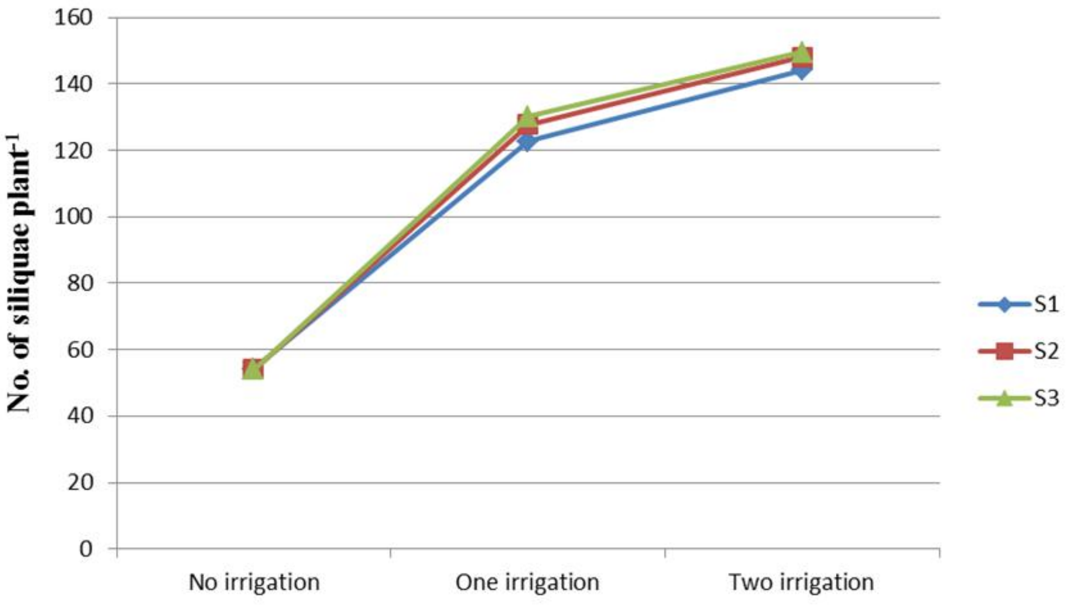

Figure 12. Inreraction efffect of irrrigation and sulphur on number of siliquae plant^{-1}

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.5 Length of siliquae

4.5.1 Effect of irrigation

Length of siliquae is an important factor which is adversely affected by the soil moisture. In the present study, number of irrigation showed significant variation in the length of siliquae (Figure 13). Among the treatment I_3 produced longest siliquae (8.062 cm). The treatment Io (control) which was received no irrigation throughout the life cycle thus produced shortest siliquae (5.874). Singh and Saran (1992) concluded that length of siliquae was significantly increased up to two irrigations at pre-flowering and fruiting stage.

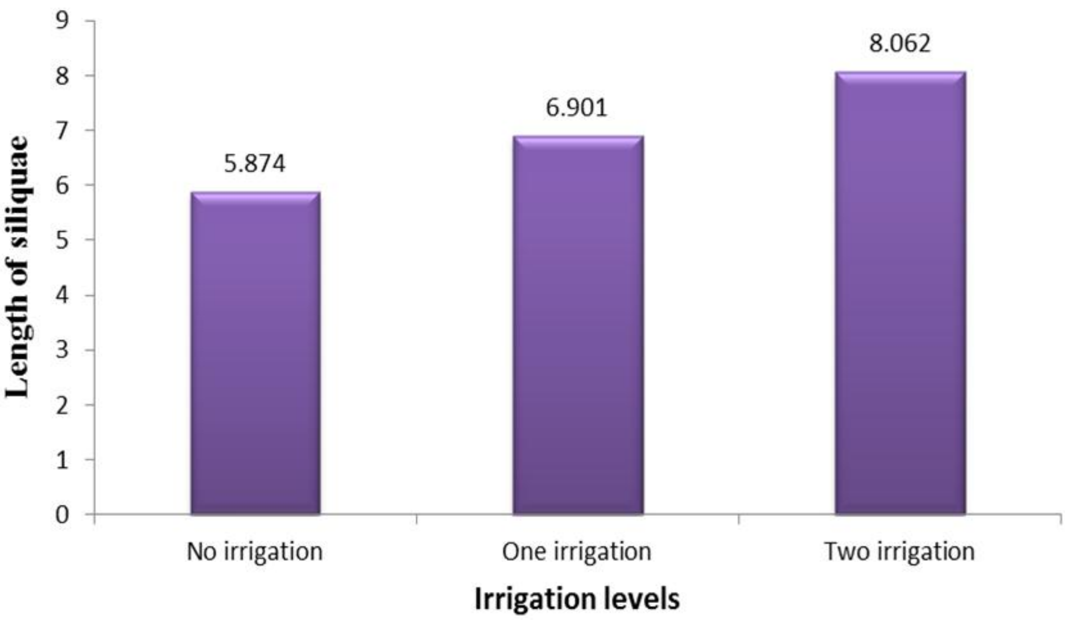

Figure 13. Efffect of of different levels of irrrigation on length of siliquae

4.5.2 Effect of Sulphur

It revealed from the Figure 14 that different levels of sulphur fertilizer significantly influenced the length of siliquae. The highest length of siliquae (7.066 cm) was recorded in 45 kg S ha^{-1} which was statistically similar with 30 kg S ha^{-1}. The shortest siliquae length (6.781 cm) was resulted in 15 kg S ha^{-1}. Piri and Sharma (2007) found that the length of siliquae was increased significantly up to 45 kg S ha^{-1} application but Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased the length of siliquae of mustard over no sulphur application.

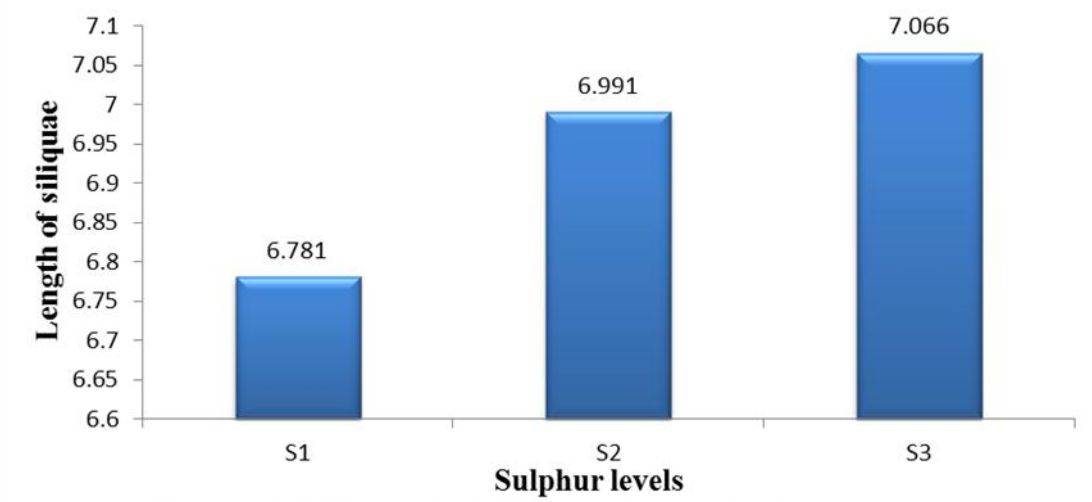

Figure 14. Efffect of of different levels of sulphur on length of siliquae

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.5.3 Interaction effect of irrigation and sulphur

From the study, it was also observed that treatment combination of irrigation and sulphur had significant effect on length of siliquae (Figure 15). Two levels of irrigation with 45 kg S ha^{-1} produced longest siliquae (8.097 cm) which was statistically similar with treatment combination of I_2S_1 and I_2S_2. Shortest siliquae (54.12) was found in I_0S_1 treatment. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that all yield contributing characters and yield of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

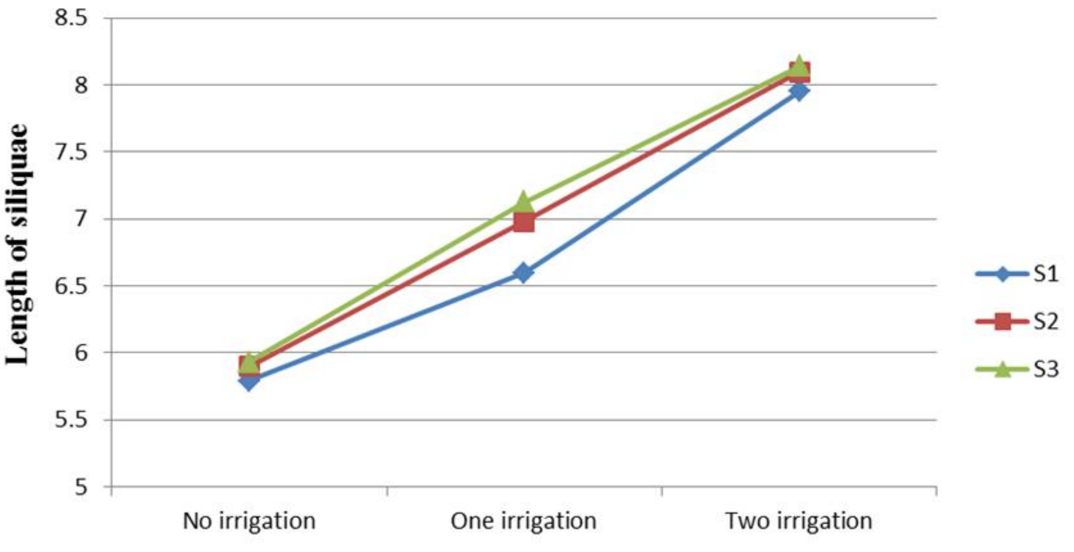

Figure 15. Inreraction efffect of irrrigation and sulphur on length of siliquae

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.6 Number of seeds siliqua^{-1}

4.6.1 Effect of irrigation

The number of seeds per siliqua was increased with the increase of irrigation number (Figure 16). The significant highest number of seeds per siliqua (21.81) was found with two irrigations. While the lowest number of seeds per siliqua (15.28) was found from the control treatment, Seed per siliqua increased with the increasing levels of irrigation due to the supply of adequate soil moisture which helped to elongate the siliqua length and have more number of seeds. Tomer *et al.* (1993) found a significant increase of seeds per siliqua with two irrigations-one at pre-flowering stage and another at fruiting stage. A number of researchers Prasad and Eshanullah (1988); Siag *et al.* (1993) and Sharma and Kumar (1989a) also observed that irrigation increased number of seeds per siliqua.

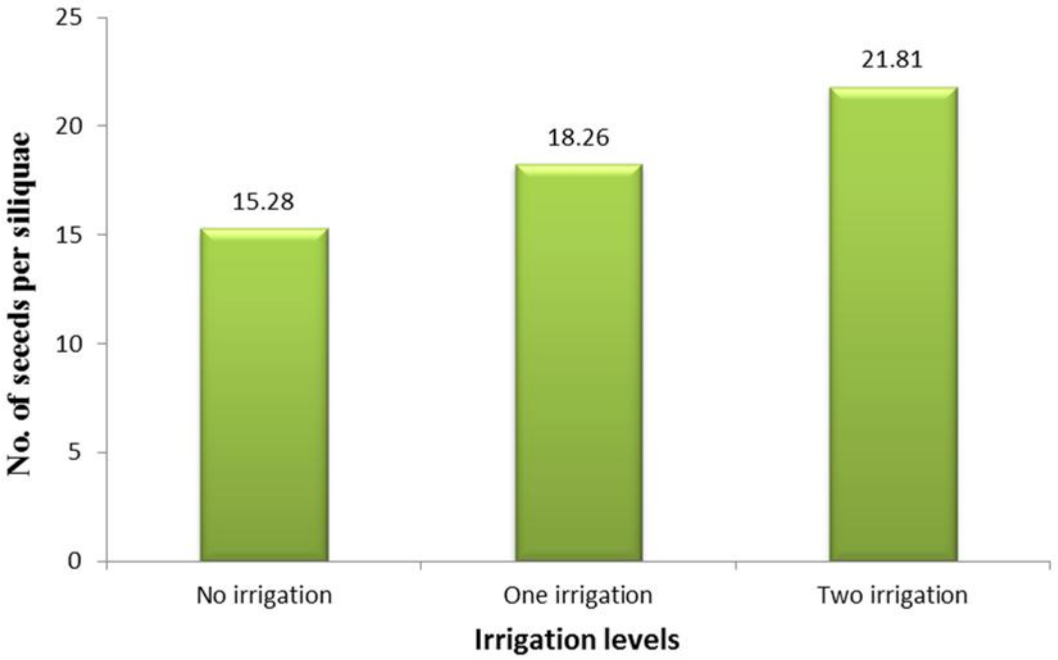

Figure 16. Efffect of of different levels of irrrigation on number of seeds per siliquae

4.6.2 Effect of sulphur

Sulphur rates significantly influenced the number of seeds per siliqua. The number of seeds per siliqua was increased with the increase of sulphur rates (Figure 17). The significant highest number of seeds per siliqua (18.63) was found with the rate of 45 kg N ha^{-1} while the lowest number of seeds per siliquae (18.18) were found with the rate of 15 kg S ha^{-1}. Seeds per siliqua increased with the increasing levels of sulphur up to a certain levels**.** Piri and Sharma (2007) found the similar result but Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased the number of seeds per siliqua of mustard over no sulphur application and Kumar *et al.* (2006) observed that Indian mustard responded significantly to the application of S upto 40 kg S ha^{-1}.

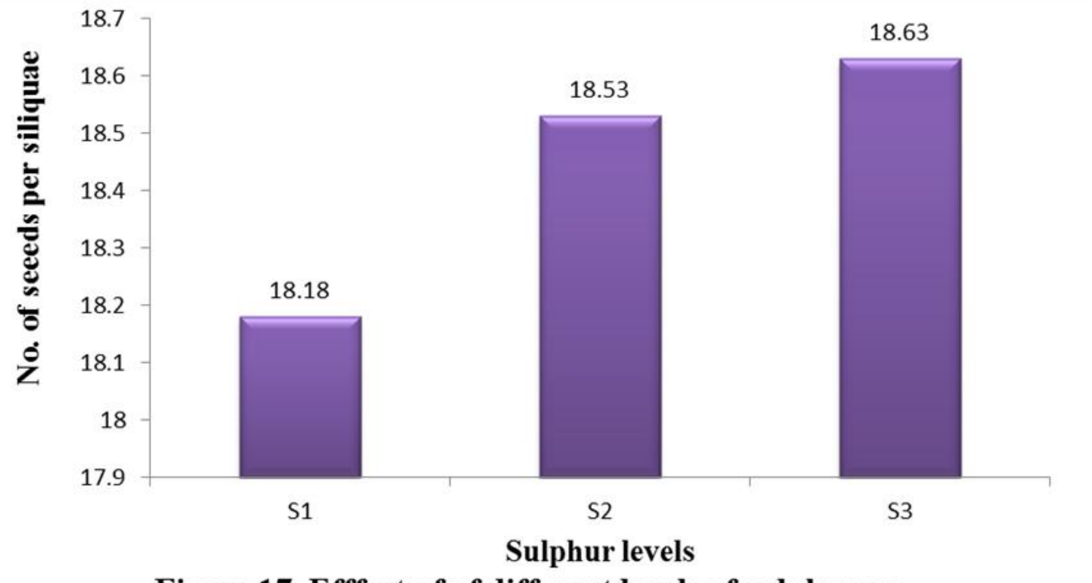

Figure 17. Efffect of of different levels of sulphur on number of seeds per siliquae

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.6.3 Interaction effect of irrigation and sulphur

From the study, it was also observed that treatment combination of irrigation and sulphur had significant effect on number of seeds per siliqua (Figure 18). Two levels of irrigation with 45 kg S ha^{-1} produced maximum number of seeds per siliqua (22.13) which was statistically similar with treatment combination of I_2S_2. Minimum numbers of seeds per siliqua (15.20) was found in I_0S_2 treatment. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that all yield contributing characters and yield of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

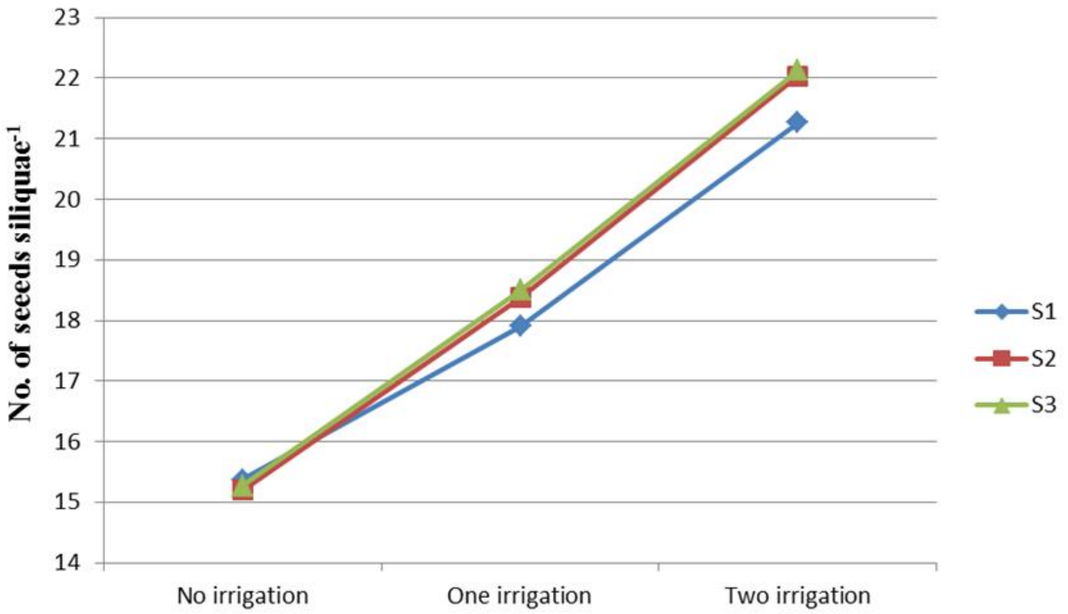

Figure 18. Inreraction efffect of irrrigation and sulphur on number of seeds siliquae^{-1}

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.7 Seed yield (g plant^{-1})

4.7.1 Effect of irrigation

Irrigation significantly increased the seed yield plant^{-1} in rapeseed. In this study, seed yield plant^{-1} increased with the increase of irrigation levels (Figure 19) Maximum seed yield plant^{-1} (6.343 g) was found from two irrigations which was higher than the other treatments. The lowest seed g plant^{-1} was found from control treatment (1.362 g). Samadder *et al*. (1997) and Sing *et al*. (1997) reported similar results in mustard.

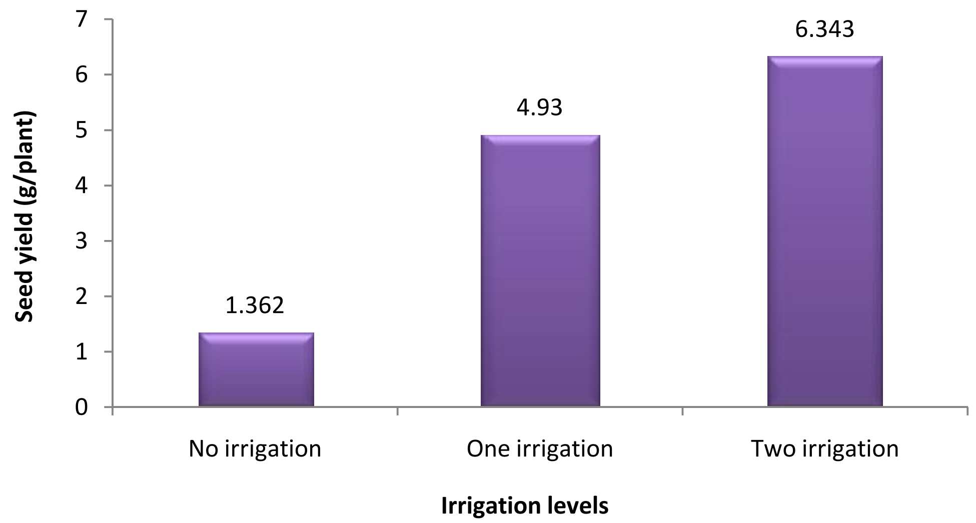

Figure 19. Effect of different levels of irrigation on seed yield per plant

4.7.2 Effect of sulphur

The seed yield per plant was significantly influenced by the sulphur treatments. The seed yield per plant varied from 4.081 to 4.292 g plant^{-1} (Figure 20) due to different treatments. The highest seed yield per plant was obtained in 45 kg S ha^{-1}. The lowest seed yield (4.081g) per plant was recorded in 15 kg S ha^{-1}. Piri and Sharma (2006) reported that maximum seed yield was achieved when 45 kg S ha^{-1} was applied. Similarly, Khalid *et al.* (2009) found increase in yield in S-supplied than that in S deficient plant.

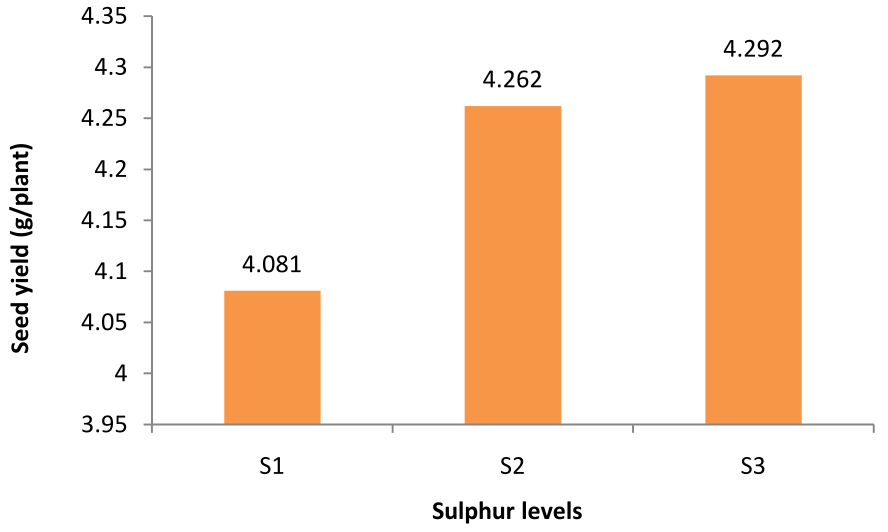

Figure 20. Effect of different sulphur levels on seed yield per plant

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.7.3 Interaction effect of irrigation and sulphur

Interaction effect of irrigation and sulphur influenced the seed yield per plant was significantly superior (6.433 g plant^{-1}) at two levels of irrigations with 45 kg S ha^{-1}. But controlled irrigation with 15 kg S ha^{-1} with gave the lowest yield (1.360 g plant^{-1}) (Figure 7) which might be referred to soil moisture deficit and inadequate S application. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that seed yield plant^{-1} of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

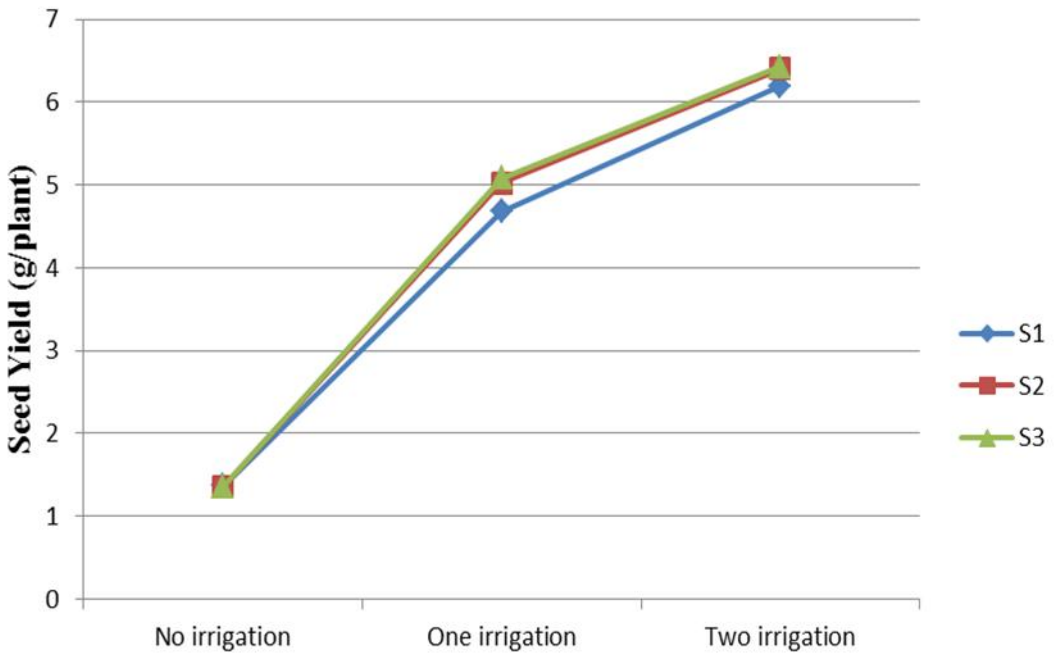

Figure 21. Efffect of different levels of irrigation and sulphur on seed yield per plant

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.8 Seed yield ha^{-1}

4.8.1 Effect of irrigation

Irrigation significantly increased the seed yield ha^{-1} in rapeseed. In this study, seed yield ha^{-1} increased with the increase of irrigation levels (Figure 21). Maximum seed yield ha^{-1} (1509 kg ha^{-1}) was found from two irrigations which was higher than the other treatments. The lowest seed yield ha^{-1} was found from control treatment (411.8 kg ha^{-1}). In control condition high mortality of seedlings resulting from shortage of soil moisture drastically reduced the yield. Samadder *et al.* (1997) reported similar results in mustard. Sharma and Kumar (1989a) observed that seed yield was increased with increasing the frequency of irrigation, Tomer and Singh (1990) reported that highest seed yield was produced by two irrigations.

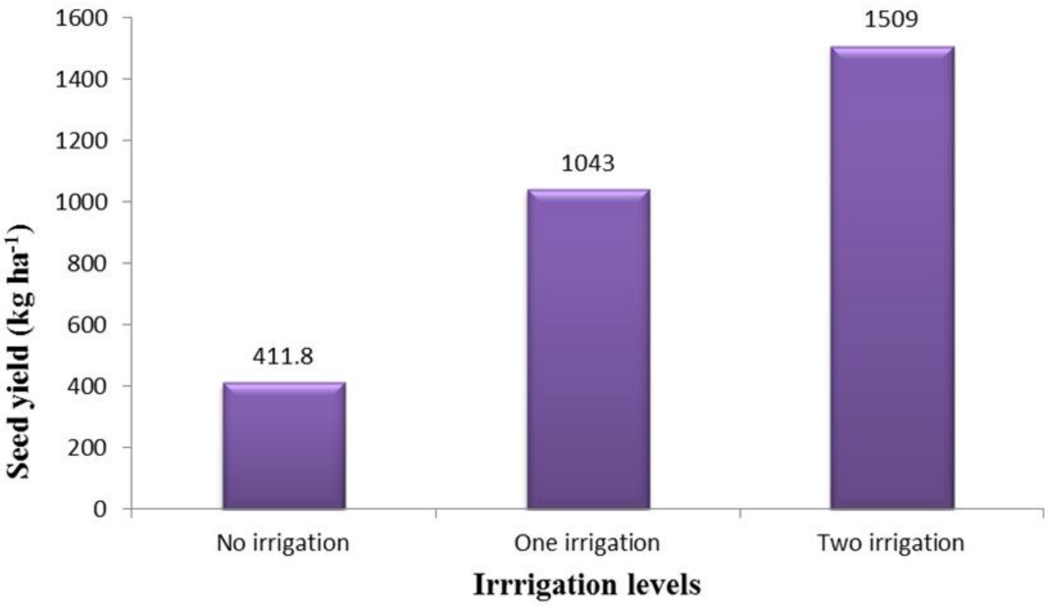

Figure 22. Effect of different irrigation levels on yield ha^{-1}

4.8.2 Effect of sulphur

Sulphur application had significant effect on number of siliqua per plant, number of seeds per siliqua and individual seed weight and the improved seed yield ha^{-1}. Figure 22 showed the significant variation in seed yield ha^{-1} at different sulphur application ranging from 957.3 kg to 1007 kg. The treatment S_3 produced the significantly highest seed yield (1007 kg ha^{-1}) which was followed by S_2 (998.4 kg ha^{-1}). This was mainly due to the fact that an optimum sulphur facilitated proper nutrients which enhanced total dry matter production and development of other yield components. Without sulphur application causes competition for nutrients and therefore, could not produce branches $plant^{-1}$, siliqua $plant^{-1}$, seeds $siliqua^{-1}$, 1000-seed weight and ultimately seed yield per unit area. Chaubey *et al.* (2001) and Verma *et al.* (2002) observed that the application of 30 kg S ha^{-1} increased seed yield per hectare of mustard over no sulphur application but Piri and Sharma (2007) found that seed yield per hectare was increased significantly up to 45 kg S ha^{-1} application.

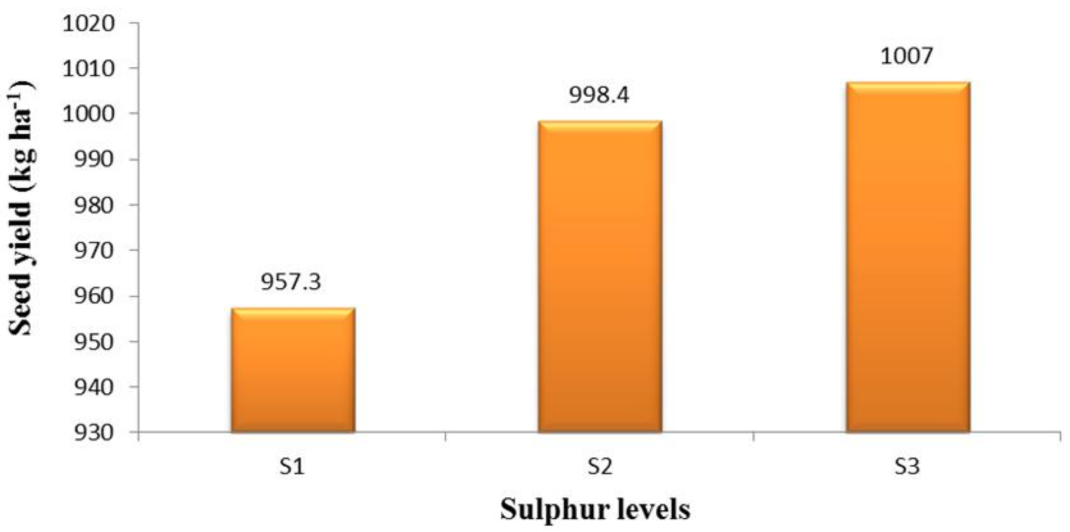

Figure 23. Effect of different sulphur levels on yield ha^{-1}

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1} and S_3 = 45 kg Sulphur ha^{-1}

4.8.3 Interaction effect of irrigation and sulphur

Interaction effect of irrigation and sulphur influenced the seed yield per hectare and seed yield was significantly superior (1536 kg ha^{-1}) at two levels of irrigations with 45 kg S ha^{-1}. But controlled irrigation with 30 kg S ha^{-1} gave the lowest yield (409.7 kg ha^{-1}) (Figure 10) which might be referred to soil moisture deficit and inadequate S application. Piri and Sharma (2007) reported the same result. On the hand Bharati and Prasad (2003) observed that seed yield per hectare of mustard increased significantly when two irrigations with 45 kg S ha^{-1} were applied.

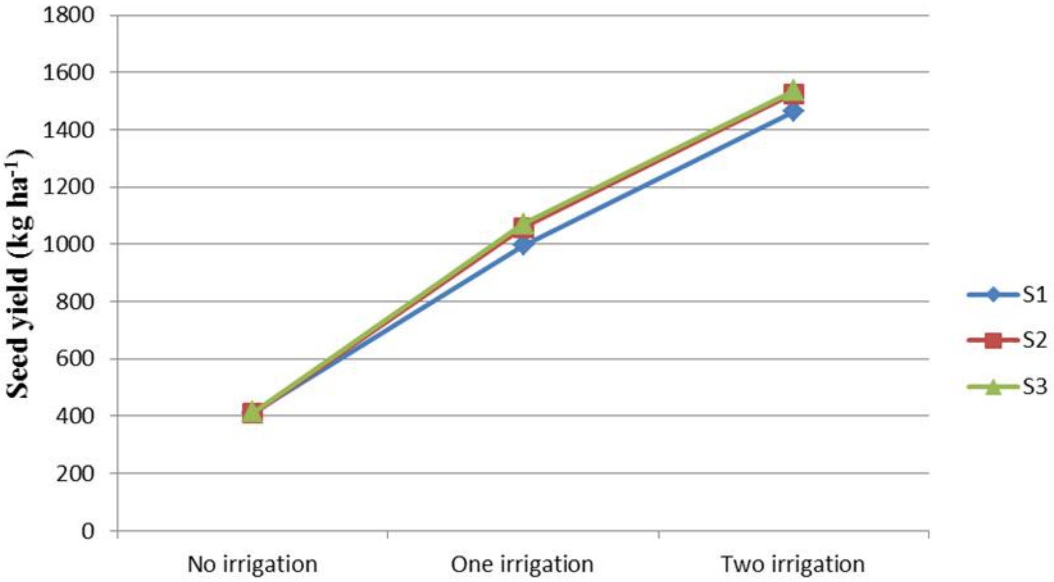

Figure 24. Interaction effect of irrigation and sulphur levels on yield ha^{-1}

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.9. Oil content

4.9.1 Effect of irrigation

From Figure 25, it was found that irrigation levels had significant effect on oil content of rapeseed. It was observed that two irrigations gave the highest oil content (43.42 %) and controlled irrigation gave the lowest oil content (42.17 %) of rapeseed. However, one irrigation (43.40 %) and two Irrigations (43.42 %) gave statistically similar oil content. But Singh and Saran (1992) observed that there was no significant effect of irrigation levels on oil content.

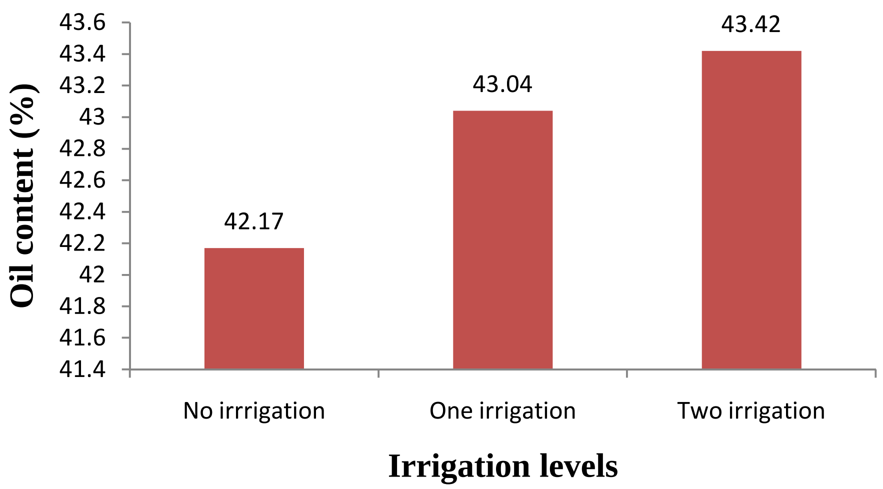

Figure 25. Effect of different levels of irrigation on oil content of rapeseed

4.9.2 Effect of sulphur

Oil content data presented in Figure 26 indicates that effect of sulphur application on oil content in seed almost similar on seed yield. However, oil content in seed increased up to highest level of sulphur application. This increase was obtained 3.66% with 45 kg S ha^{-1} over 15 kg S ha^{-1}. Sawarkar *et al.* (1987) found that increasing the rates of applied S from 0 to 60 kg ha^{-1} increased the average oil content of mustard from 40.46 to 45.05%. Increased in oil content of mustard also observed by Piri and Sharma (2006) who reported that an application of 45 kg S ha^{-1} increased oil content of mustard.

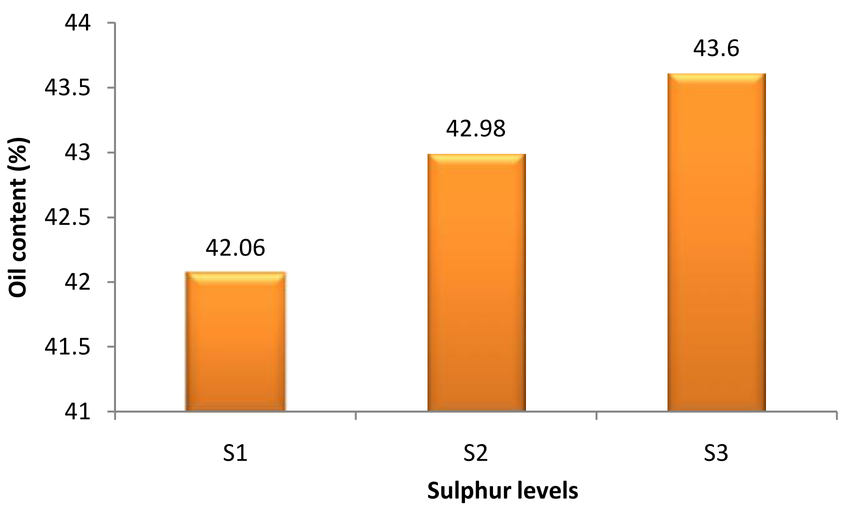

Figure 26. Effect of different levels of sulphur on oil content of rapeseed

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.9.3 Interaction effect of irrigation and sulphur

It was seen that the treatment combination of two irrigations and 45 kg S ha^{-1} gave the highest oil content (44.40 %) of rapeseed (Table 1). The combination of controlled irrigations and 15 kg S ha^{-1} gave the lowest oil content (41.57 %) of rapeseed. Bharati and Prasad (2003) also observed that oil content and oil yield of mustard significantly increased upto two irrigations with 45 kg S ha^{-1}.

Table 1. Interaction effect of irrigation and sulphur on oil content of rapeseed

Irrigation Level	Sulphur Level	Oil content (%)
No irrigation (I_0)	S_1	41.57 g
	S_2	42.20 f
	S_3	42.73 de
One irrigation (I_1)	S_1	42.33 ef
	S_2	43.13 cd
	S_3	43.67 b
Two irrigation (I_2)	S_1	42.27 ef
	S_2	43.60 bc
	S_3	44.40 a
$LSD_{0.05}$		0.4707
CV (%)		0.62

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.10 Nitrogen

According to Table 2 it is apparent that different irrigation levels enhanced the N content. The highest N content (2.117%) was found from the plots where two irrigations was applied and the lowest (1.273%) from the plots where irrigations was not applied.

It is evident from Table 3 that different levels of sulphur significantly influence the nitrogen contents of mustard. Highest nitrogen content (1.781%) was obtained from 45 kg S ha^{-1}. The lowest nitrogen contents (1.674%) were recorded from 15 kg S ha^{-1}. These results corroborated with the results of Ali and Taman (1997).

From the study, it was also observed that treatment combination of irrigation and sulphur enhanced the N content mustard. Highest nitrogen contents (2.140%) was obtained from I_2S_3 i.e. two irrigation with 45 kg S ha^{-1}. The lowest nitrogen contents (1.200%) were recorded from I_0S_1 treatment (Table 4).

Table 2. Effect of irrigation on nitrogen, phosphorus, potassium, and sulphur content of rapeseed plant

Irrigation	Content in plant (%)			
	N	P	K	S
No irrigation (I_0)	1.237 c	0.09711 c	3.073 c	0.2944 c
One irrigation (I_1)	1.838 b	0.1203 b	3.292 b	0.3811 b
Two irrigation (I_2)	2.117 a	0.1306 a	3.960 a	0.4256 a
$LSD_{0.05}$	0.05853	0.00771	0.1242	0.03179

4.11.1 Phosphorus

From the present study it was observed that different irrigation levels enhanced the P content. The highest P content (0.1306%) was found from the plots where two irrigations was applied and the lowest (0.09711%) from the plots where irrigations was not applied (Table 2).

According to (Table 3) it is apparent that different sulphur levels enhanced the P content. The highest P content (0.1189%) was found from 45 kg S ha^{-1} and the lowest (0.1131%) from 15 kg S ha^{-1}.

From the Table it is observed that treatment combination of irrigation and sulphur enhanced the P content mustard. Highest P contents (0.1337%) was obtained from I_2S_2 i.e. two irrigation with 30 kg S ha^{-1}. The lowest nitrogen contents (0.09467%) were recorded from I_0S_1 treatment (Table 4).

Table 3. Effect of sulphur on nitrogen, phosphorus, potassium, and sulphur content of rapeseed plant

Sulphur	Content in plant (%)			
	N	P	K	S
S_1	1.674 c	0.1131 c	3.336 c	0.3422 c
S_2	1.736 b	0.1189 a	3.443 b	0.3689 b
S_3	1.781 a	0.1160 b	3.547 a	0.3900 a
$LSD_{0.05}$	0.03248	0.001894	0.03248	0.009187

S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur $ha^{-1}$and S_3 = 45 kg Sulphur ha^{-1}

4.12.2 Potassium

According to (Table 2) it is apparent that different irrigation levels enhanced the K content. The highest K content (3.960%) was found from the plots where two irrigations was applied and the lowest (3.073%) from the plots where irrigations was not applied.

It is evident from (Table 3) that different levels of sulphur significantly influence the potassium contents of mustard. Highest potassium content (3.547%) was obtained from 45 kg S ha^{-1}. The lowest potassium contents (3.336%) were recorded from 15 kg S ha^{-1}.

From the study, it was also observed that treatment combination of irrigation and sulphur enhanced the N content of mustard. Highest K content (4.147%) was obtained from I_2S_3 i.e. two irrigations with 45 kg S ha^{-1} and the lowest nitrogen contents (2.937%) were recorded from I_0S_1 treatment (Table 4).

Table 4. Interaction effect of irrigation and sulphur on nitrogen, phosphorus, potassium, and sulphur content of rapeseed plant

Irrigation x sulphur	Content in plant (%)			
	N	P	K	S
I_0S_1	1.200 g	0.09467 f	2.937 g	0.2600 g
I_0S_2	1.237 fg	0.1000 e	3.127 f	0.2933 f
I_0S_3	1.273 f	0.0966 f	3.157 f	0.3300 e
I_1S_1	1.740 e	0.1167 d	3.247 e	0.3600 d
I_1S_2	1.843 d	0.1230 c	3.293 de	0.3833 c
I_1S_3	1.930 c	0.1213 c	3.337 d	0.4000 b
I_2S_1	2.083 b	0.1280 b	3.823 c	0.4067 b
I_2S_2	2.127 ab	0.1337 a	3.910 b	0.4300 a
I_2S_3	2.140 a	0.1300 b	4.147 a	0.4400 a
LSD(0.05)	0.05626	0.003280	0.05626	0.01591
CV (%)	1.67	1.58	1.05	2.49

I_0 = Control, I_1 = One Irrigation, I_1 = Two Irrigation, S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

4.13.3 Sulphur

From the present study it was observed that different irrigation levels enhanced the S content. The highest S content (0.4256%) was found from two irrigations and the lowest (0.2944%) from controlled irrigation (Table 2).

Table 3 shows that different levels of sulphur influenced the S content. The highest sulphur content (0.39%) was obtained by 45 kg S ha^{-1} and the lowest (0.342%) was under 15 kg S ha^{-1}. Appendix IV shows that sulphur content was significant by the application of different sulphur doses. These results corroborated with the results of Ali and Taman (1997).

From the Table 4, it is observed that treatment combination of irrigation and sulphur also enhanced the S content of mustard. Highest S contents (0.440%) was obtained from I_2S_3 i.e. two irrigation with 45 kg S ha^{-1}. The lowest S contents (0.260%) were recorded from I_0S_1 treatment.

4.14 Correlation and regression studies

Statistical relationship between seed yield and plant height, seed yield and effective siliquae plant^{-1}, seed yield and and seeds siliquae^{-1}, seed oil content and sulphur concentration in plant, seed yield and oil content of rapeseed has been found out. The regression lines of these parameters were also shown in Fig. 27, 28, 29 and 30.

4.14.1 Seed yield and plant height

There is a direct significant and positive relationship between seed yield and plant height of rapeseed which has been confirmed with correlation co-efficient r^2 = 0.9873 (Fig. 27). The relationship was more evident y = 36.01x – 1993.9 and also showing gradual increase of plant height.

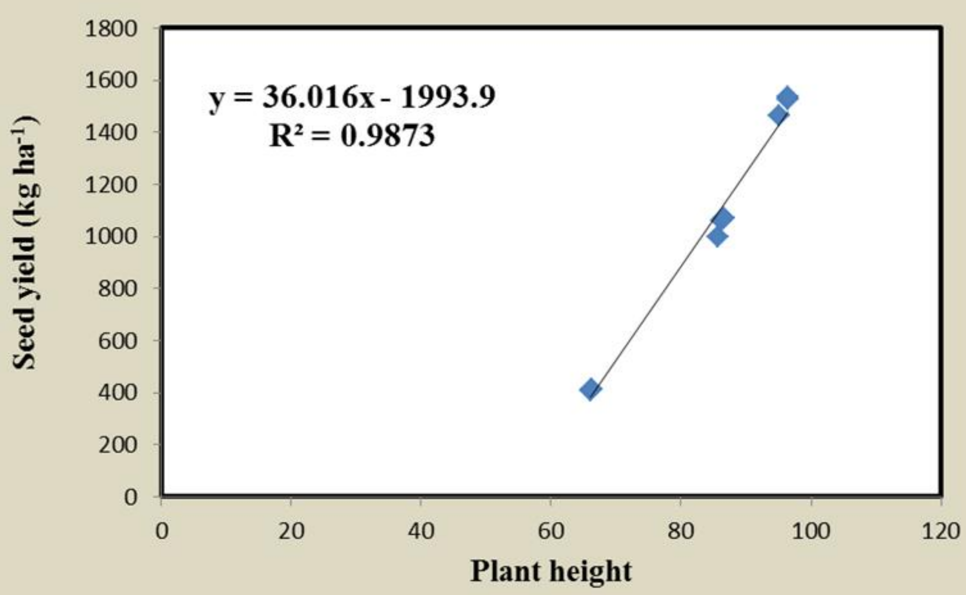

Figure 27. Relationship between seed yield and plant height

4.14.2 Seed yield and siliquae plant^{-1}

In order to observe the relationship between seeds yield and siliquae plant^{-1} Figure 28 was done. The seed yield was positively and significantly correlated with siliquae plant^{-1} (r^2 = 0.9489). The line of regression of y = 10.924x – 207.32 is shown in Fig. 28. The positive slope indicates that the seed yield and effective siliquae plant^{-1} are directly correlated i.e. increase in seed yield result in an increase in effective siliquae plant^{-1} of rapeseed.

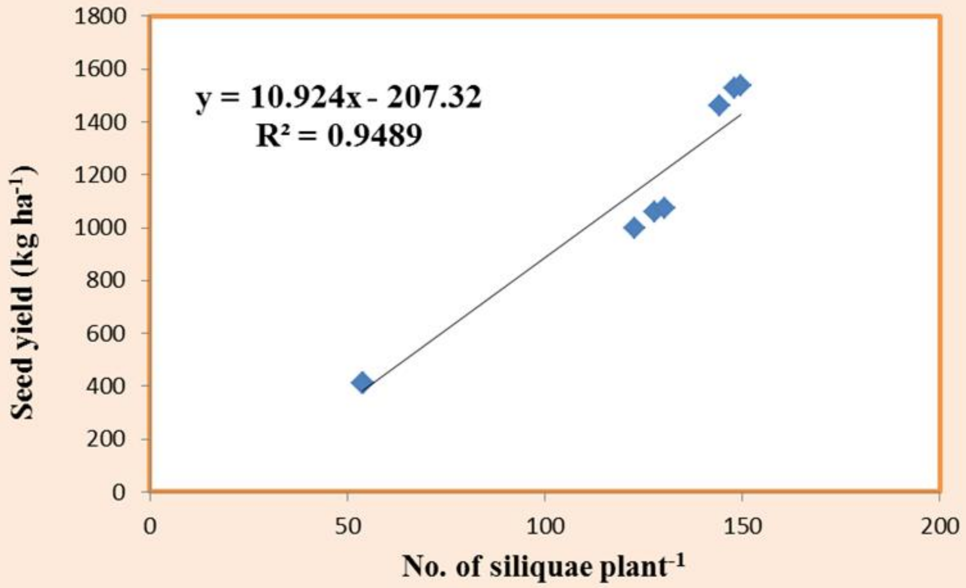

Figure 28. Relationship between seed yield and siliquae plant^{-1}

4.14.3 Seed yields and seed siliquae^{-1}

It is shown from Fig. 29 that there was a direct significant and positive relationship between seed yield and seed siliquae^{-1} having y = 164.56x – 2049.7. The correlation co-efficient (r^2 = 0.9793) was found out significant at 5% level of probability. The positive slope indicates that seed yield and seed siliquae^{-1} directly correlated i.e. increase in seed siliquae^{-1} result in an increase in seed yield.

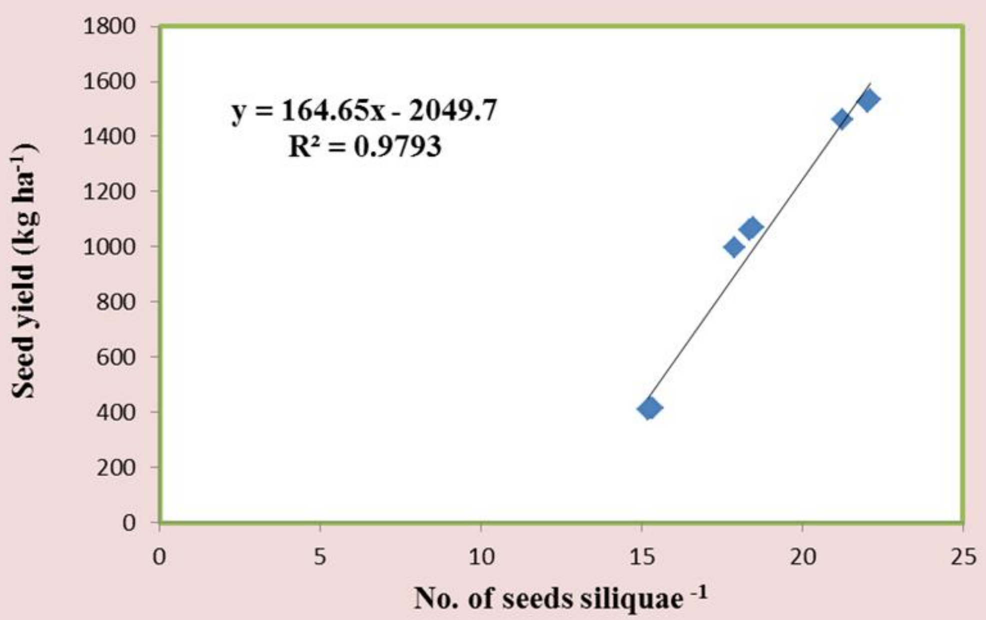

Figure 29. Relationship between seed yield and seeds siliquae^{-1}

4.14.4 Oil content and sulphur concentration of rapeseed

There is a direct significant and positive relationship between Oil content and sulphur concentration of rapeseed which has been confirmed with correlation co-efficient r^2 = 0.6714 (Fig. 30). The relationship was more evident y = 1.1846x + 38.53 and also showing gradual increase of sulphur concentration.

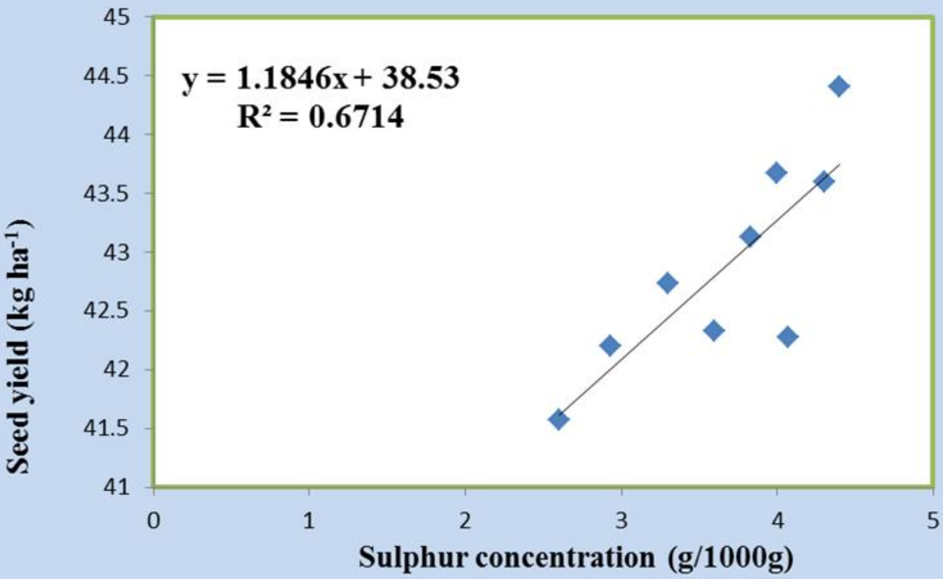

Figure 30. Relationship between grain oil content and sulphur concentration in plant

CHAPTER V
SUMMARY AND CONCLUSION

An experiment entitled "Effect of irrigation and sulphur on the yield of rapeseed (*Brassica campestries*)" was conducted during Rabi season (October 2013 – February 2014), at Agronomy field of Sher-e-Bangla Agricultural University. The treatment comprised 3 levels of irrigation and 3 levels of sulphur. At maturity, the crop was harvested on 10th February, 2014. Plot wise yield and yield components were recorded. Grain samples were analyzed for examining the oil contents and straw samples were chemically analyzed for examining the nutrient (N, P, K, and S) contents. All the data were statistically analyzed. The results are summarized below.

Significant variation was found in plant height among the irrigation levels. The maximum plant height was found from two irrigations. A progressive increase of plant height was observed up to 45 kg S ha^{-1}. Plant heights were significantly influenced by the interaction effect of irrigation and sulphur at harvest. Application of two irrigations along with 45 kg S ha^{-1} showed higher plant height on the other hand, lower plant height were observed at control irrigations along with 15 kg S ha^{-1}.

The number of primary branches per plant, secondary branches per plant, number of siliquae per plant increased progressively with the increasing level of irrigation. The maximum numbers of primary, secondary branches per plant; number of siliquae per plant were found when two irrigations were applied at 25 and 53 DAS. The lowest results were found from the control treatment.

The number of primary branches per plant, secondary branches per plant, number of siliquae per plant increased progressively with the increasing level of Sulphur. The average numbers of primary, secondary branches per plant, number of siliquae per plant were found at higher rate when 45 kg S ha^{-1} was applied which was statistically similar with 30 kg S ha^{-1}.

Interaction of irrigation and S significantly influenced branch number and number of siliquae per plant. Application of two levels of irrigation with 45 kg S ha^{-1} gave significantly higher number of primary branches (7.243), secondary branches (8.930), and siliquae number per plant (149.5) which was statistically similar with the treatment combination of two levels of irrigation and 30 kg S ha^{-1}.

Irrigations had significant effect on the siliquae length and seeds per siliquae. Among the irrigation treatments, two irrigations at 25 and 53 DAS produced the highest siliquae length (8.062 cm) and seeds per siliquae (21.81) which was statistically different from other irrigation treatments. The highest siliquae length (7.066 cm) and seeds per siliquae (18.63) obtained at 45 kg S ha^{-1} which was statistically similar with 30 kg S ha^{-1}.

Interaction effect of irrigation and S significantly influenced the siliquae length and seeds per siliqua. Application of two levels of irrigation with 45 kg S ha^{-1} gave significantly higher number of siliquae length (8.14 cm) and seeds per siliqua (22.13) which was statistically similar with the treatment combination of two levels of irrigation and 30 kg S ha^{-1} and lowest was found from the controlled irrigation with 15 kg S ha^{-1} application.

Seed yield depends on the different yield contributing characters. The seed yield ha^{-1} was significantly influenced by the number of irrigation and two irrigations produced the highest seed yield (1505 kg ha^{-1}) which was statistically different from other irrigations and least seed yield (411.8 kg ha^{-1}) was found at unirrigated condition. The seed was increased significantly up to 45 kg S ha^{-1}. The highest seed yield (998.2 kg ha^{-1}) was found at higher rate of 45 kg S ha^{-1} which was statistically similar with 30 kg S ha^{-1} and lowest seed yield (957.3 kg ha^{-1}) was found at a rate of 15 kg S ha^{-1}.

Seed yield was increased significantly by the interaction effect of irrigation and S application. Significant seed yields of 1527 kg ha^{-1} was obtained at two levels of irrigations along with 45 kg S ha^{-1} which was statistically similar with the treatment combination of two levels of irrigation and 30 kg S ha^{-1}.

Irrigation had a little effect on oil content of rapeseed. Higher oil content (43.42 %) was obtained at two levels of irrigation and lowest oil content (42.17 %) was found at control irrigation. Sulphur had significant effect on oil content of rapeseed. Higher oil content (43.60 %) was obtained at 45 kg S ha^{-1} and lowest oil content (42.06 %) was found at 15 kg S ha^{-1}. Higher oil content of 44.40 % was obtained at two irrigations along with 45 kg S ha^{-1}.

Effect of irrigation and sulphur on nutrients content (N, P, K, and S) in straw was statistically significant. In straw, the highest nitrogen (2.117%), phosphorus (0.1306%), potassium (3.96%) and sulphur (0.4256%) was obtained when two irrigations was applied which was statistically different from other irrigations. On the other hand, in straw, the highest nitrogen (1.781%), potassium (3.547%) and sulphur (0.39%) was obtained at 45 kg S ha^{-1} but the highest phosphorus (0.1189%) was obtained at 30 kg S ha^{-1}.

Nutrients content (N, P, K, and S) in straw was increased significantly by the interaction effect of irrigation and S application. The highest nitrogen (2.147%), potassium (4.147%) and sulphur (0.44%) was obtained when two irrigations with 45 kg S ha^{-1} was applied but the highest phosphorus (0.1337%) was obtained when two irrigations with 30 kg S ha^{-1} was applied.

From the present study, it may be concluded that irrigation and sulphur influenced the growth, yield and yield components of rapeseed. Among the irrigation levels twice irrigations at 25 and 53 DAS gave the best results. Among the sulphur treatments, 45 kg S ha^{-1} gave the best result and it was statistically similar with 30 kg S ha^{-1}. The interaction effects of twice irrigations with 30 kg S ha^{-1} were found the most effective in respect of seed yield.

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APPENDICES

Appendix I: Morphological, Physical and chemical characteristics of initial soil (0-15 cm depth)

A. **Morphological characteristics of experimental field**

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

B. Physical composition of the soil

Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-do-
Clay	36.66	-do-
Texture class	Clay loam	-do-

C. Chemical composition of the soil

SI.	Soil characteristics	Analytical data	Method employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner & Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lancster, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner , 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha	89.50	Pratt ,1965
8	Available S (ppm)	16.00	Hunter, 1984
9	PH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Appendix II: Monthly average of temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from October 2013 to February 2014

Year	Month	Air temperature (^{o}c)			Relative humidity MI	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2013	October	30.6	24.6	27.60	77	326	142.20
	November	29.1	19.8	24.45	70	03	197.63
	December	27.1	15.7	21.4	64	Trace	217.03
2014	January	25.3	18.2	21.75	68	0	165.10
	February	31.3	19.4	25.35	61	0	171.01

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

Appendix III: Source of variation, degree of freedom and mean square of yield attributes

Source of variation	d. f.	Mean square				
		Plant height	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of siliquae plant^{-1}	L si
R	2	1.449	0.146	0.098	16.139	0.
I	2	2075.483**	36.964**	71.651**	21643.112**	1(
Error I	4	0.441	0.034	0.158	13.855	0.
S	2	1.233**	0.3329**	0.252**	42.668**	0.
I x S	4	0.611*	0.072*	0.062^{NS}	12.307**	0.
Error II	12	0.124	0.016	0.026	1.478	0.
Total	26					
CV (%)		0.42	2.25	2.51	1.11	1.

Note: Single and double asterisks indicate cignificant at 5% and 1% levels respectively. NS means non-significant, R= Replication, I= Irrigation and S= Sulphur.

Appendix IV: Source of variation, degree of freedom and mean square of seed yield, grain oil content and N, P, K, S concentration in straw

Source of variation	d.f.	Mean square					
		Seed yield (kg ha^{-1})	Oil content (%)	Concentration of N (%)	Concentration of P (%)	Concentration of K (%)	Concentration of S (%)
R	2	115.4	0.343	0.010	0.191	0.011	0.091
I	2	2727458.1**	3.734**	1.820**	26.434**	1.920**	4.001**
Error I	4	5947.4	0.153	0.002	0.347	0.009	0.059
S	2	6384.1**	5.434**	0.026**	0.751**	0.100**	0.516**
I x S	4	1664.2**	0.212 NS	0.004*	0.019NS	0.016**	0.030*
Error II	12	187.9	0.070	0.001	0.034	0.001	0.008
Total	26						
CV (%)		1.39	0.62	1.67	1.58	1.05	2.49

Note: Single and double asterisks indicate cignificant at 5% and 1% levels respectively. NS means non-significant, R= Replication, I= Irrigation and S= Sulphur.

Appendix V: Effect of irrigation on yield contributing characters, yield and oil content of rapeseed:

Irrigation levels	Plant height	Primary branches per	Secondary branches per plant	Siliquae per plant (No.)	Length of siliquae	Seeds per siliquae (No.	Seed yield (g plan	Seed yield (kg	Oil content (%)

		plant (No.)	(No.)		(cm)	)	t^{-1})	ha^{-1})	
I_0	66.18 c	3.271 c	3.319 c	54.02 c	5.874 c	15.28 c	1.362 c	411.8 c	42.17 b
I_1	86.20 b	6.404 b	7.350 b	126.9 b	6.901 b	18.26 b	4.930 b	1037 b	43.04 a
I_2	95.97 a	7.064 a	8.754 a	147.3 a	8.062 a	21.81 a	6.343 a	1505 a	43.42 a
$LSD_{0.05}$	0.8692	0.2413	0.5202	4.872	0.4627	0.3463	0.3152	0.8692	0.5120
CV (%)	0.42	2.25	2.51	1.11	1.88	1.69	2.45	1.39	0.62

Note: Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05), I_0 = Control, I_1 = One Irrigation, I_1 = Two Irrigation

Appendix VI: Effect of sulphur on yield contributing characters, yield and oil content of rapeseed:

Sulphur levels	Plant height	Primary branches per plant (No.)	Secondary branches per plant (No.)	Siliquae per plant (No.)	Length of siliquae (cm)	Seeds per siliquae (No.)	Seed yield (g plant^{-1})	Seed yield (kg ha^{-1})	Oil content (%)
S_1	83.08 a	5.363 b	6.287 b	107.0 c	6.781 b	18.18 b	4.081 b	957.3 b	42.06 c
S_2	82.9	5.652	6.529	110.0	6.99	18.5	4.26	998.4	42.9

	0 a	a	ab	b	1 a	3 a	2 a	a	8 b
S_3	83.08 a	5.724 a	6.608 a	111.3 a	7.066 a	18.63 a	4.292 a	998.2 a	43.60 a
$LSD_{0.05}$	0.3617	0.1299	0.2557	1.249	0.1339	0.3199	0.1077	15.91	0.2717
CV (%)	0.42	2.25	2.51	1.11	1.88	1.69	2.45	1.39	0.62

Note: Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05); I_0 = Control, I_1 = One Irrigation, I_1 = Two Irrigation, S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}

Appendix VII: Interaction effect of irrigation and sulphuron yield contributing characters, yield and oil content of rapeseed:

Treatment	Plant height	Primary branches plant^{-1} (No.)	Secondary branches plant^{-1} (No.)	Siliquae plant^{-1} (No.)	Length of siliquae (cm)	Seeds siliquae^{-1} (No.)	Seed yield (g plant^{-1})	Seed yield (kg ha^{-1})	Oil content (%)
I_0S_1	66.33 e	3.237 e	3.310 d	54.12 f	5.79 d	15.37 e	1.367	412.7	41.57 g
I_0S_2	66.03 e	3.297 e	3.233 d	53.95 f	5.897 d	15.20 e	1.360	409.7	42.20 f
I_0S_3	66.17 e	3.280 e	3.413 d	53.98 f	5.930 d	15.27 e	1.360	413	42.73 de
I_1S_1	85.63 d	6.133 d	7.103 c	122.7 e	6.597 c	17.90 d	4.683	996	42.33 ef
I_1S_2	86.3 c	6.430 c	7.467 c	127.8 d	6.980 b	18.37 cd	5.023	1059	43.13 cd
I_1S_3	86.67 c	6.650 bc	7.480 c	130.2 c	7.127 b	18.50 c	5.083	1055	43.67 b
I_2S_1	95.13 b	6.720 b	8.447 b	144.2 b	7.950 a	21.27 b	6.193	1463	42.27 ef
I_2S_2	96.37 a	7.230 a	8.887 ab	148.1 a	8.097 a	22.03 a	6.403	1526	43.60 bc
I_2S_3	96.4 a	7.243 a	8.930 a	149.5 a	8.140 a	22.13 a	6.433	1527	44.40 a
$LSD_{0.05}$		0.2250	0.4430	2.163	0.2320	0.5541	0.1866	27.55	0.4707
CV (%)	0.42	2.25	2.51	1.11	1.88	1.69	2.45	1.39	0.62

Note: Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05); I_0 = Control, I_1 = One Irrigation, I_1 = Two Irrigation, S_1 = 15 kg Sulphur ha^{-1}, S_2 = 30 kg Sulphur ha^{-1}and S_3 = 45 kg Sulphur ha^{-1}