RESPONSE OF RAPESEED TO THE MANAGEMENT OF SULPHUR AND WEEDS

A THESIS

BY

MANIR HOSSAIN

REGISTRATION NO. 05-01754

MASTER OF SCIENCE
IN
AGRONOMY

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

June, 2011

RESPONSE OF RAPESEED TO THE MANAGEMENT OF SULPHUR AND WEEDS

BY

MANIR HOSSAIN

REGISTRATION NO. 05-01754

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka-1207
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

Approved By:

Prof. Dr. Md. Fazlul Karim
Supervisor

Prof. Dr. Parimal Kanti Biswas
Co-Supervisor

Prof. Dr. A.K.M. Ruhul Amin

Chairman
Department of Agronomy

CERTIFICATE

This is to certify that thesis entitled ***"Response of rapeseed to the management of sulphur and weeds"*** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY** embodies the result of a piece of *bona fide* research work carried out by Mr. Manir Hossain, Roll No. 01754, Registration No. 05-01754 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Prof. Dr. Md. Fazlul Karim)
Supervisor

June 2011

DEDICATED
TO
MY BELOVED PARENTS

ABBREVIATIONS AND UNITS

Abbreviation

AEZ	Agro Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
C.V.	Coefficient of Variation
cv.	Cultivar
DAE	Days After Emergence
DAS	Days After Sowing
DM	Dry matter
E	East
et al.	*et alibi* (and others)
etc.	*et cetra* (and so on)
FAO	Food and Agricultural Organization
Fig.	Figure
HI	Harvest Index
HYV	High Yielding Variety
i.e.	id est (that is)
LSD	Least Significant Difference
MJ	Mega Joule
N	North
NNC	National Nutritional Council
PD	Population Density
SAU	Sher-e-Bangla Agricultural University
TDM	Total Dry Matter
viz.	Videlicet (namely)

Unit

%	Percentage
^0C	Degree Celsius
cm	Centimeter
cm^2	Square Centimeter
g	Gram
ha	Hectare
kcal	Kilocalorie
kg	Kilogram
m	Meter
q	Quintal
t	Ton

ACKNOWLEDGEMENT

At the outset, the author would like to express his profound gratefulness to the almighty Allah 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. Fazlul Karim, Professor, Department of Agronomy, 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 Porimol Kanti Biswas, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207 for his valuable suggestions, continuous and cordial help to successfully complete the study programme.

The author wishes to express deepest gratitude, profound appreciation and immense indebtedness to all the teachers and staff members of the Department of Agronomy, 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 Shaikh Mujibur Rahman Agricultural University is acknowledged with thanks.

The author wishes his profound gratitude to his parents, and brother, Mominul Islam for inspiring him in preparing the manuscript. He also expresses his cordial thanks to all of his friends specially Ashraful Islam for encouragement and help.

May Allah bless and protect them all.

June 2011

The Author

LIST OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

THESIS
ABSTRACT

RESPONSE OF RAPESEED TO THE MANAGEMENT OF SULPHUR AND WEEDS

An experiment was conducted at the agronomic field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2010 to February 2011 to find out the optimum rate of sulphur and appropiate time of weeding for BARI Sharisha -14. The experiment was carried out with four levels of sulphur application (control, 15 kg/ha, 30 kg/ha, 45 kg/ha) and 4 levels of weed management (control, one hand weeding at 15 DAS, two hand weeding at 15 DAS and 30 DAS and three hand weeding at 15 DAS, 30 DAS and 45 DAS). The experiment was laid out in split-plot design with three replications.Sulphur application and weed management significantly influenced the growth, development and yield of the mustard. Among the sulphur application, the application of sulphur @ 30 kg/ha resulted the maximum plant height, dry matter weight, number of siliqua plant^{-1} , number of seeds siliqua^{-1}, number of seeds plant-1, number of branches plant^{-1}, 1000-seed weight, seed yield plant^{-1} and biological yield. Maximum seed yield plant^{-1} was observed with 30 kg S/ha(S_2) and it was 39.99%, 16.73% and 6.24% higher than control (S_0), 15 kg S/ha (S_1) and 45 kg S/ha (S_2) respectively.Three weeding – at 15 DAS (vegetative stage), 30 DAS (pre-flowering stage) and 45 DAS (reproductive stage) resulted the best biological and economic yield as the yield components like number of branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, number of seeds plant^{-1}, 1000-seed weight were found to be highest with these three weeding. Plant height as well as dry matter accumulation were also found to be maximum with three weeding.. The increased seed yield plant^{-1} with three weeding (W_3) was 11.58 % and 23.89 % higher than one weeding (W_1) and without irrigation (W_0).In most of the cases the interaction of 30 kg S/ha with three weeding were found to give the best results. The highest seed yield as well as biological yield was found with the interaction of three weeding and 30 kg S/ha which was statistically identical with the interaction of two weeding and 30 kg S/ha . Maximum number branches plant^{-1}, number of siliqua plant^{-1}, seeds siliqua and 100-seed weight was also found from the interaction of three weeding and 30 kg S/ha. Two weeding combined with 30 kg S/ha produced almost similar result.

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Rapeseed and mustard belong to the family Cruciferae are important crops and currently ranked as the world's third important oil 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 (Downey and Rimmer, 1990). 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, 2004). 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, 1998). About one-third of the total requirement of oil is met by local production of rapeseed and mustard (BBS, 2004).

At present about 0.300 million hectares of land is under rapeseed and mustard cultivation in Bangladesh with a production of 0.225 million tons (BCA, 2009). The average seed yield of rapeseed and mustard is 0.71 t ha^{-1} in this country (BBS, 2004), 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, 2001). 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 cultivars ranges between 1.4 and 2.1 t ha^{-1} (BARI, 2002). However, the yields in farmer's 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.

Among many agronomic factors responsible for low yield, imbalanced and injudicious use of fertilizers also limits the crop production. 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 cv.

Mustard has a high demand of S, with approximately 16 kg of S required to produce 1 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 and Abdin, 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 interveinal 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 CGR significantly increased with increasing level of sulphur up to 20 kg S. ha^{-1} and LAI up to 40 kg S. ha^{-1}.

Yield of rapeseed is also hampered by different pests. Among them weed is an important factor in reducing yields. Weeds affect the plant growth and reducies yields particularly in the early stages of development. It was observed that the seed yield reduced by 46% with lower quality seed when plants are not weed free during their growth stages (Dixit and Gautam, 1996). Two hand weeding or mechanical weeding at 20 and 40 days after seeding (DAS) resulted in higher yield compared to that of control (Kaul and Das, 1986).

Weed competition in mustard is more serious in early stage; because crop growth during winter (rabi) season remains slow during the first 4-6 weeks after sowing. However, during later stage it grows vigorously and has suppressing effect on weeds. As this crop is grown in poor soil with poor management practices, weed infestation is one of the major causes of low productivity. Among the factors responsible for the low productivity of the mustard, weeds alone cause 20-30% yield reduction, which may go up to 62% (Singh, 1992). Weeds being injurious, harmful or poisonous are a constant source of trouble for the successful growth and development of crops. Weeds compete with crops for light, moisture, space and plant nutrients and other environmental requirements and consequently interfere with the normal growth of crops. Weeds pose severe problem for crop husbandry, reducing the soil fertility and moisture, act as alternate host for insect & pest and develop a potential threat to the succeeding crops.

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

a) to find out the suitable rate of sulphur fertilizer for the cultivation of rapeseed plant.

b) to find out the proper number of weeding for getting higher yield of rapeseed .

c) to study the combined effect of sulphur fertilizer and weeding for higher yield of rapeseed .

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Rapeseed is an important oil crop in Bangladesh, which can contribute to a large extent in the national economy. The research works done on this crop with respect to agronomic practices are inadequate. Only some limited studies have so far been done in respect of agronomic management practices of the crop. However, a number of such-studies have been carried out in other parts of the world. Some of the studies relevant to the present line of work have been reviewed.

2.1 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 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) were obtained with 40 and 60 kg S/ha.

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 .

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

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 (13.28 and 14.12 q/ha, respectively).

Prakash and Singh (2002) found that seed yield, protein and oil contents, and oil yield increased with the increase in sulphur rate up to 40 kg/ha 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 siliqua, test weight, seed yield and stover yield. The increase in these parameters was observed up to 60 kg S/ha. Increase in plant height with an increase in rate of sulphur application has also been reported by a number of workers (Khanpara *et al*., 1993; Tomar *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 siliqua plant-1, seeds siliqua-1, length of siliqua and test weight only up to 30 kg ha-1.

Abdin *et al*. (2003) conducted a field experiment and it was concluded from these experiment that the yield and quality of rapeseed-mustard could be optimized with the application of 40 kg S/ha.

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 CGR 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 responded significantly to the application of S . The seed and stover yields increased in the linear order up to 40 kg S /ha. The highest seed yield (2035 kg S ha^{-1}) at 40 kg S/ ha was 27.59% higher in comparison to the yield at control.

Prasad *et al*. (2003) found that S at 20 kg/ha 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 differs among the varieties depending on their genetic makeup. There are three species of cruciferous *Brassica* viz. *Brassica campestris*, *Brassica juncea* and *Brassica napus* every one of which differs from one another with respect to plant growth, development and yield.

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

Shukla (2004) reported that dry matter yield increased with increasing levels of S application.

Nepalia (2005) reported that application of sulphur up to 60 kg/ha significantly increased crop dry matter, leaf area index and productivity of mustard.

Sah *et al*. (2005) reported that the yield attributes and yields increased significantly with the increasing levels of S up to 40 kg/ha.

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

Duhan *et al*. (2006) reported that application of sulphur significantly increased the grain and straw yields 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 sulphur 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. Application of 40 kg S/ha gave the highest seed yield (18.37 g/ha), 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. S at 15, 30 and 45 kg/ha 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, siliqua length, seed and straw yield as a result of S application up to 40 kg/ha. Seeds per siliqua and harvest index were improved with application of only 20 kg S/ha. Thus, to obtain higher growth and seed yield of Indian mustard under subtropical western tract of Uttar Pradesh, application of 40 kg S/ha together with recommended doses of other major nutrients was found to be the most appropriate fertilizer combination.

Piri and Sharma (2007) reported that both irrigation and S 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 was increased from 0 to 45 kg S/ha, whereas with 1 or 2 irrigations, the seed yield increased with 30 kg S/ha.

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.

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

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 100 g^{-1}), 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 highest biomass (9058 kg ha^{-1}) and seed yield (1656 kg ha^{-1}) but these were statistically at par with 30 kg S ha^{-1}.

Dabhi *et al*. (2010) found that maximum growth, yield attributes, and uptake of sulphur 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 increased significantly with increasing rates of sulphur up to 40 kg S /ha . However, the difference between 40 and 60 kg S/ha for growth and yield attributes were non-significant. Increase in siliquae/plant, seeds/siliquae, 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 over control.

Bharose *et al.* (2011) reported that application of varying doses of sulphur had significant effect on the seed yield of Toria. The seed yield increased from 11.80 to 15.89qha^{-1} progressively with increase in level of sulphur from 0.00 to 20.00 kg ha^{-1} and yield decreases with the application of higher dose of sulphur (40.00 kg ha^{-1}). The result is in conformity with the findings of Singh *et al*. (1997), Tomar *et al*., (1996).

Kumar *et al*. (2011) conducted a field experiment and observed that among the sulphur level, 45 kg S/ha being at par with 30 kg S/ha gave significantly higher seed yield (1.18 and 1.26 tonnes/ha).

Piri *et al*. (2011) conducted a field experiment in two years and observed that plant height increased with increasing level of sulphur at all growth stages in both the years. However, the difference between 0 and 15 kg S/ha at 90 DAS in both the years and at harvest in second year, 15 and 30 kg S/ha at 90 DAS and at harvest in first year and at 45 DAS in second year and between 30 and 45 kg S/ha at 45 DAS in second year and between 15 and 30kg 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 meristematic activities resulting in higher apical growth and expansion of photosynthetic surface. Increase in plant height with an increase in rate of sulphur 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 significantly 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 seeds $siliqua^{-1}$, 1000-seeds weight, seed yield. Among sulphur levels application of 60 kg S hs^{-1} gave significantly higher seed yield (20.98 kg ha^{-1}) than control,20 and 40 kg S ha^{-1} owing to better expression of siliqua length, number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, 1000-seed 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 60 kg 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}.

2.2 Effect of number of weeding

Among the factors responsible for low productivity of mustard, weeds alone cause 20-30% yield reduction, which may go up to 62% (Singh, 1992).

Kaul and Das (1986) reported that two hand weeding or mechanical weeding at 20 and 40 days after seeding (DAS) resulted in higher yield as compared to that of control .

Bhargava (1991) demonstrated that biological yield, harvest index and siliqua productions per plant were positively correlated with higher seed yield of rapeseed and mustard but number of seed per siliqua was negatively correlated. Correlation studies between biological yield and seed yield was significant and suggested that higher seed yield can be obtained from vigorous genotypes that give greater biomass.

Bhadoria and Chauhan (1995) reported that weeding for two times gives more seed yield in mungbean, soybean and mustard.

Dixit and Gautam (1996) observed that the seed yield was reduced by 46% with lower quality seed when plants were not weed free during their growth stages.

Tekale *et al.* (2005) found that the growth and yield attributes showed significant positive correlation with seed yield, whereas dry weight of weeds showed significant negative correlation with seed yield of Indian mustard.

Rashid et al. (2007) conducted a field experiment and observed that plant responded positively to the treatment variables.Seed yield was positively related with number of branches per plant, number of siliquae per plant, number of seeds per siliqua and 1000-seed weight.Plant remained weed free up to 40 DAS gave more seed (17.7%) and oil (18.1%) yield than no weed control treatment. The tallest plants with maximum number of branches was produced with two weeding at 20 and 40 DAS. The plant height and the number of branches per plant were found minimum with no weeding. Yield attributes like number of siliquae per plant, seeds per siliqua and 1000 seed weight were found significantly affected with number of weeding. Plants with two hand weeding at 20 DAS and 40 DAS produced significantly higher number of siliquae per plant (65.72), number of seeds per siliqua (18.64) and 1000-seed weight (2.86 g) which was followed by treatment one hand weeding at 20 DAS. Plants under weed competition (W_0) gave the lowest yield parameters.

Plants remained free from weed competition up to 45 DAS (W_2) and gave significantly more seed yield (1812.20 kg ha^{-}).

Shaheenuzzamn *et al.* (2010) conducted a field experiment and found that different treatments had significant effect on plant height. The highest plant height (124.7 cm) was recorded in hand weeding (weed free) treated plot and the lowest (110.5) was observed in no weeding check plot.It indicated that the weed control treatments improved the number of pods/plant. The 1000 seed weight (g) was significantly affected by different treatments. Maximum 1000 seed weight of 2.58 (g) was observed in hand weeding (weed free) treated plot and minimum 2.35 (g) was in control plot. They also found that maximum (1245.00kg) grain yield was recorded in hand weeding plot which was statistically similar to Dual Gold 960 EC @ 1.0 L/ha treated plot. The minimum (1009.5kg) grain yield was recorded in no weeding check plots. Statistical analysis of the data revealed that harvest index (HI) was non-significantly affected by different treatments .

The above findings revealed that the yield of different rapeseed and mustard varieties differed among themselves due to their genetic makeup as expressed by the difference in their plant height, number of branches per plant, siliquae per plant, siliqua length, number of seed per plant and 1000-seed weight. These yield- contributing characters are also influenced by the sulphur application and ultimately the yield of these varieties varies with number of weeding.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

A field experiment on mustard with different sulphur dose and weeding levels was conducted in the Rabi season (November to February, 2011) to evaluate the optimum sulphur dose and appropriate time of weeding.

3.1. Experimental Site

The research was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2010 to February 2011. The experimental field is located at $90^0$335´ E longitude and $23^0$774´ N latitude at a height of 9 meter above the sea level (BCA, 2004). The land was medium high and well drained.

3.2. Climate

The average maximum and minimum temperature during the cropping period ranged between 25.4^0C to 29.6^0C and12.7^0C to19^0C, respectively. The humidity varied from 68% to 77%. The full sun shine hour between 5.5 to 5.7 only and rainfall during the experimentation period ranged between 7.7 mm to 34.4mm.

3.3. Soil

The soil of the experimental site belongs to the agro-ecological region of „Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The top soil is silty clay loam in texture. Organic matter content was very low (0.82%) and soil pH varied from 5.47 - 5.63.

3.4 Experimental materials

The BARI Sharisha-14 was used as sowing materials collected from BARI, Bangladesh.

3.5. Experimental treatments

There were two treatment factors in this experiment, viz. sulphur dose (S) and weeding (W). Different sulphur doses were control (S_0), 15 kg/ha (S_1), 30 kg/ha (S_2) and 45 kg/ha (S_3). Weed management levels were control (W_0), one hand weeding at 15 DAS (W_1), two hand weeding at 15 DAS and 30 DAS (W_2) and three hand weeding at 15 DAS, 30 DAS and 45 DAS(W_3).

3.6 Experimental layout and design

The experiment was laid out in a two factor Split Plot design with three replications. Sulphur was given in main plot and weeding was done in sub-plots. Each replication was divided into 4 equal main plots randomly. Further each main plot was also divided into 4 sub plots. Thus the total plot number was 48. The size of each plot was 4 m × 2 m (8 m^2). The distance between two adjacent unit plots and between two main plots was 0.5 m and distance between two replication was 1 m.

3.7. Crop Husbandry

3.7.1. Land Preparation

The experimental field was ploughed with power tiller drawn rotavator. Subsequent cross ploughing was done followed by laddering to make the land level. All weeds, stubbles and residues were removed from the field.

3.7.2. Fertilization

The experimental plots were fertilized with a recommended dose of 300, 180, 100, 5 and 10 kg ha^{-1} of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP), Zinc Oxide (ZnO) and Boric Acid, respectively along with sulphur as per treatment. During final land preparation one half of the urea and total amount of all other fertilizers were applied and incorporated into soil. Rest of the urea was top dressed on 11 Deccember, 2010 at 34 days after sowing (DAS).

3.7.3. Sowing of seeds

Seeds of BARI Sharisha-14 were sown on 8th November, 2010 maintaining row spacing. Sowing was done continuously in rows.

3.7.4. Weeding and thinning

The experimental plots were found to be infested with different kinds of weeds, viz. Bathua (*Chenopodium album* L.), Bermuda Grass (*Cynodon dactylon*), Nut sedge (*Cyperus rotundus* L.), Biskatali (*Polygonum hydropiper* L.) Water Pepper (*Polygonum hydropiper* L.), Goose grass (*Eleusine indica*) etc. Weeding was done in each plot as per experimental treatments manually with „nirani". Thinning was done in all the unit plots with care to maintain a constant plant population in each row. Finally plants were kept at 5 cm distance in rows.

3.7.5. Irrigation

Irrigation were given at 3 times with pipe and finally one flood irrigation was given at 8 January 2011 (60 DAS).

3.7.6. Pest and disease management

The crop was sprayed with Malathion 60 EC to prevent infestation of mustard aphids at siliqua formation stage. Dithane M-45 was also applied in soil immediately after irrigation to prevent soft rot of plants.

3.7.7 Harvesting and Processing

At maturity when 80% of the pod turned chocolate brown to black in colour, the crop was harvested. The crops under the replication number one (R-I) was harvested on 9 February, 2011 (92 DAS), the crops under the replication number two (R-II) was harvested on 11 February, 2011 (94 DAS), and the crops under the replication number three (R-III) was harvested on 13 February, 2011 (96 DAS). Harvesting was done in the morning to avoid shattering. An area of 1 m^2 was harvested from the centre of each plot at ground level with the help of a sickle. Prior to harvesting, ten plants were sampled randomly from within the harvest area and uprooted for data recording. The harvested plants from each plot were bundled separately, tagged and brought to a clean cemented threshing floor. The crop was sun dried by spreading them over the floor and seeds were separated from the siliqua by beating the bundles with bamboo sticks.

The seeds thus collected were dried in the sun for reducing the moisture about 9% level. The stovers were also dried in the sun. Seed and stover yield were recorded. The biological yield was calculated as the sum of the seed yield and stover yield

3.8. Data Collection

Ten plants were taken out randomly from each plot leaving the border plants. This destructive sampling was done to record the following data at an interval of 15 days starting from 15 DAS (just after first weeding) except weed data. Weed data was collected at an interval of 15 days starting from 20 DAS.

i Plant height (cm)

ii Leaf area per plant (cm^2)

iii Dry weight of leaves per plant (g)

iv Dry weight of stem per plant (g)

v Dry weight of inflorescence per plant (g)

vi Above ground total dry matter per plant (g)

vii Weed dry matter weight per square meter (g)

viii Number of branches per plant

ix Number of siliquae per plant

x Number of seeds per siliqua

xi Number of seeds per plant

xii 1000 seed weight (g)

xiii Seed yield per plant (g)

xiv Seed yield per hectare (tons)

xv Stover yield per hectare (tons)

xvi Biological yield per hectare (tons)

xvii Harvest Index (%)

3.8.1. Plant height

The height of ten plants was measured from ground level (stem base) to the tip of the plant. Mean plant height was calculated and expressed in cm.

3.8.2. Leaf area per plant

To measure the leaf area of plant, three plants were selected randomly and data were recorded. Mean leaf area per plant was calculated and expressed as square meter.

3.8. 3. Dry weight of leaf per plant

Dry weight of separated leaves was measured with a digital balance at 45,

60, 75 and 90 DAS. Weight was measured in gram. Weight of ten plants was then calculated for the weight of single plant and shown as gram per plant.

3.8.4. Dry weight of stem per plant

Dry weight of separated stems were measured with a digital balance at 45, 60, 75 and 90 DAS. Weight was measured in gram. Average weight of ten plants was then calculated and expressed in gram per plant.

3.8.5. Dry weight of inflorescence per plant

Dry weight of inflorescence was measured with a digital balance at 45, 60, 75 and 90 DAS. Weight was taken in gram. Average weight of siliqua of ten plants was then recorded and shown as gram per plant.

3.8.6. Above ground total dry mater per plant

After measuring the fresh weight, the plants were separated into stem, leaf and siliqua and they were kept in separate packet. Then they were dried in an electric oven at 70^0 C for 48 hours. Weight of ten plants was then divided by ten to get the weight of single plant.

3.8.7. Weed dry matter weight per square meter

Weed samples were collected using 100cm x 100cm quadrate from randomly selected places from each plot at an interval of 15 days starting from 20 DAS. Dry weight of weeds was recorded.

3.8.8. Number of branches per plant

The number of branches of ten randomly sampled plants were counted and recorded. Average value of ten plants was recorded as number of branches per plant.

3.8.9. Numbers of siliquae per plant

Siliquae of ten plants were counted and divided by ten, which indicated the number of siliquae per plant.

3.8.10. Number of seeds per siliqua

The number of seeds was counted by splitting twenty siliqua which were sampled randomly from sampled plants and then mean value was determined.

3.8.11. Number of seeds per plant

Number of seeds per plant was calculated by multiplying the number of siliqua per plant and number of seed per siliqua.

3.8.12. Weight of 1000-seed

From the seed stock of each plot, 1000 seeds were randomly counted. Then the weight was taken by a digital balance. The 1000-seed weight was recorded in gram.

3.8.13. 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 calculated.

3.8.14 .Seed yield per hectare

After threshing, cleaning and drying, total seed yield from the harvested area (1 m^2) was recorded and was converted to kg ha^{-1}.

3.8.15. Stover yield per hectare

After the separation of seeds from plant, the straw and shell per plot was dried separately and the weight was recorded. These were then converted into stover yield (kg ha^{-1}).

3.8.16. Biological yield per hectare

The summation of seed yield and stover yield per hectare gave the biological yield.

3.8.17. Harvest Index

Harvest Index was calculated by the following formula of Donald (1963).

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

3.9. Statistical analysis

The data were analysed following Analysis of Variance (ANOVA) technique and mean differences were adjusted by the t-test (Gomez and Gomez, 1984) using the statistical computer programme ALPHA and MSTAT-C v.1.2. Means were compared by using DMTR test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the performance of rapeseed as influenced by sulphur and weeding. The results of the present investigation have been presented, discussed and compared as far as possible with the results of other researchers.

4. 1. Plant height

Effect of sulphur

In the initial stage up to 30 DAS the growth of the line was very slow and then the crop remained in rosette form. Stem elongation started with the initiation of reproductive phase of development. The rapid increase of plant height was observed from 30 DAS to 75 DAS. After 75 DAS the growth of plant height became very slow. In the initial stage the plant canopy was very small and competition was mainly negligible. When the canopy began to increase the competition was started for aerial space. Sulphur caused significant variation in plant height of rapeseed (Table 1). Plant height increased with increasing level of sulphur at all growth stages.The application of sulphur @30kg/ha ultimately produced the tallest plant than S_0 (control), S_1 (15 kg/ha) and S_3 (45 kg/ha). The increase in plant height with the application of sulphur is attributed to increased metabolic processes in plants. Sulphur application seems to have promoted meristematic activities resulting in higher apical growth and expansion of photosynthetic surface. Increase in plant height with an increase in rate of sulphur application has also been reported by a number of workers (Khanpara *et al.*, 1993; Tomar *et al.*, 1997; Rana *et al.*, 2001).

Table 1. Plant height of rapeseed at different age as affected by different sulphur rate

Treatments	Days after sowing (DAS)					
	15	30	45	60	75	90
S0	7.86	21.82 d	42.60 d	74.27 d	83.64 d	84.94 d
S1	7.80	29.97 c	50.24 c	81.65 c	90.03 c	92.03 c
S2	7.85	35.04 a	55.62 a	87.21 a	96.36 a	97.16 a
S3	7.81	32.69 b	53.03 b	84.84 b	93.41 b	95.31 b
SX value	**NS**	**0.13**	**0.13**	**0.13**	**0.13**	**0.13**
CV(%)	**4.08**	**2.57**	**1.52**	**0.94**	**0.87**	**0.86**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Effect of weeding

Significant variation was found among the weeding treatment (Table2) for plant height of rapeseed. The highest plant height at 30,45, 60, 75 and 90 DAS was found from the treatment W_3 (Three hand weeding at 15 DAS, 30 DAS and 45 DAS), which was significantly different from the other treatments (W_0 ,W_1 and W_2) and it was followed by W_2 and lowest was found from W_0. Weeding facilitates the plants to have more resources which rendered the increased plant height and also more number of branches per plant in this experiment. This result corroborated with the findings of (Gaffer, 1984) .The lowest plant height was found for the control treatment (no weeding) throughout the life cycle. No significant difference was found at 15 DAS because at that time there was no weeding treatment in any plot.

Table 2. Plant height of rapeseed at different age as affected by different number of weeding

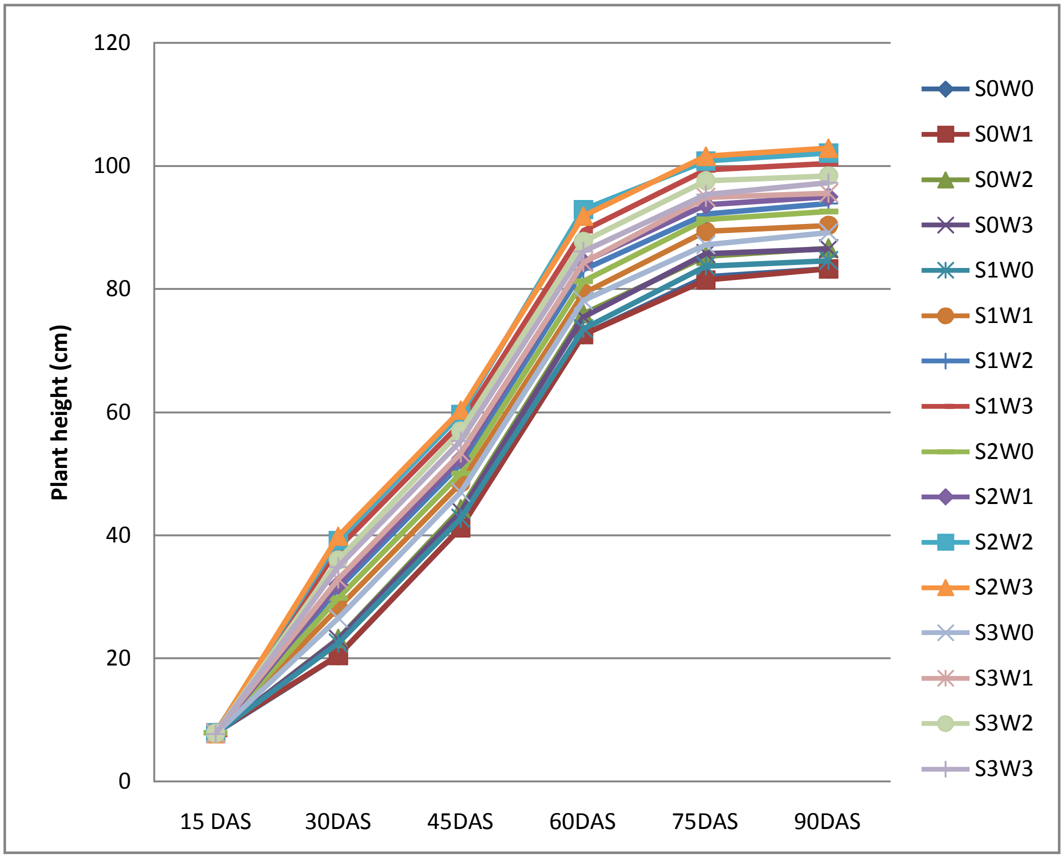
Treatments	Days after sowing (DAS)					
	15	30	45	60	75	90
W_0	7.81	24.81 d	45.17 d	76.58 d	86.14 d	87.24 d
W_1	7.86	28.37 c	48.88 c	80.39 c	89.75 c	91.05 c
W_2	7.90	32.22 b	52.92 b	84.41 b	93.97 b	95.27 b
W_3	7.75	33.93 a	54.33 a	86.62 a	95.48 a	96.58 a
SX value	**NS**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**
CV (%)	**3.74**	**1.73**	**1.03**	**0.63**	**0.56**	**0.55**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance .

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Interaction effect of sulphur and weeding

The interaction effect of sulphur and weeding had a great effect on the plant height of rapeseed in this study (Fig. 1). Significant differences of plant height were found in every stages of growth except at the early stage (15 DAS). This was due to the slow growth rate and also for the reason of no weeding before 15 DAS.



S_0 = Control — W_0 =Control

S_1 = 15 kg Sulphur per ha — W_1 =One hand weeding at 15 DAS

S_2 = 30 kg Sulphur per ha — W_2 =Two hand weeding at 15,30 DAS

S_3 = 45 kg Sulphur per ha — W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig 1. Plant height of rapeseed at different ages as affected by the interaction between sulphur rate and weeding

Maximum plant height was observed in the treatment S_2W_3 (30kg S/ha and three weeding) in all the stages of life cycle. The lowest plant height was found with all sulphur doses (control, 15 kg/ha, 30 kg/ha and 45 kg/ha) with no weeding (control). The plant response in terms of height due to the combined treatment was found higher in the middle of growth stage (from 45 DAS to 75 DAS) because of better growth. The maximum plant height at harvest was obtained from the treatment S_2W_3 which was statistically identical with S_2W_2.

4.2 Above ground dry matter weight

Effect of sulphur

Sulphur dose significantly influenced the total dry matter production in the rapeseed. Significant variation was found at all the growth stages except 15 and 30 DAS (Table 3). Accumulation of dry matter was very slow at 15 DAS and found no significant differences of production with fertilizer variations. In case of 45 DAS and 60 DAS significant difference was found for dry matter production. Among the sulphur dose, the treatment S_2 produced the highest dry matter which was statistically identical to S_3 where dry matter accumulation was lowest in the treatment S_0 and S_1.

Table 3. Total above ground dry matter weight per plant of rapeseed at different age as affected by different sulphur rate

Treatments	Days after sowing (DAS)					
	15	30	45	60	75	90
S0	0.35	1.228b	11.31c	23.55d	31.12d	33.03d
S1	0.35	1.298ab	11.76b	28.04c	35.61c	37.22c
S2	0.34	1.346a	12.21a	32.86a	40.13a	41.79a
S3	0.34	1.304ab	12.01a	29.52b	37.09b	38.57b
SX value	**NS**	**0.01**	**0.05**	**0.10**	**0.10**	**0.10**
CV(%)	**0.93**	**1.18**	**1.00**	**1.68**	**1.32**	**1.18**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Effect of weeding

Significant variation was found in total dry matter per plant with the time among the different weeding treatment except early growth stages. Distinct differences were observed in dry matter production after 45 DAS when two hand weeding was already done (Table 4).

Table 4. Total above ground dry matter weight per plant of rapeseed at different age as affected by different number of weeding

Treatments	Days after sowing (DAS)					
	15	30	45	60	75	90
W_0	0.36	1.249a	11.44c	24.49d	32.06d	33.89d
W_1	0.34	1.280a	11.69b	26.83c	34.30c	36.07c
W_2	0.35	1.320a	12.06a	30.81b	38.28b	39.86b
W_3	0.34	1.327a	12.09a	31.84a	39.31a	40.79a
SX value	**NS**	**NS**	**0.03**	**0.11**	**0.11**	**0.11**
CV (%)	**5.06**	**1.75**	**0.41**	**2.07**	**1.63**	**1.53**

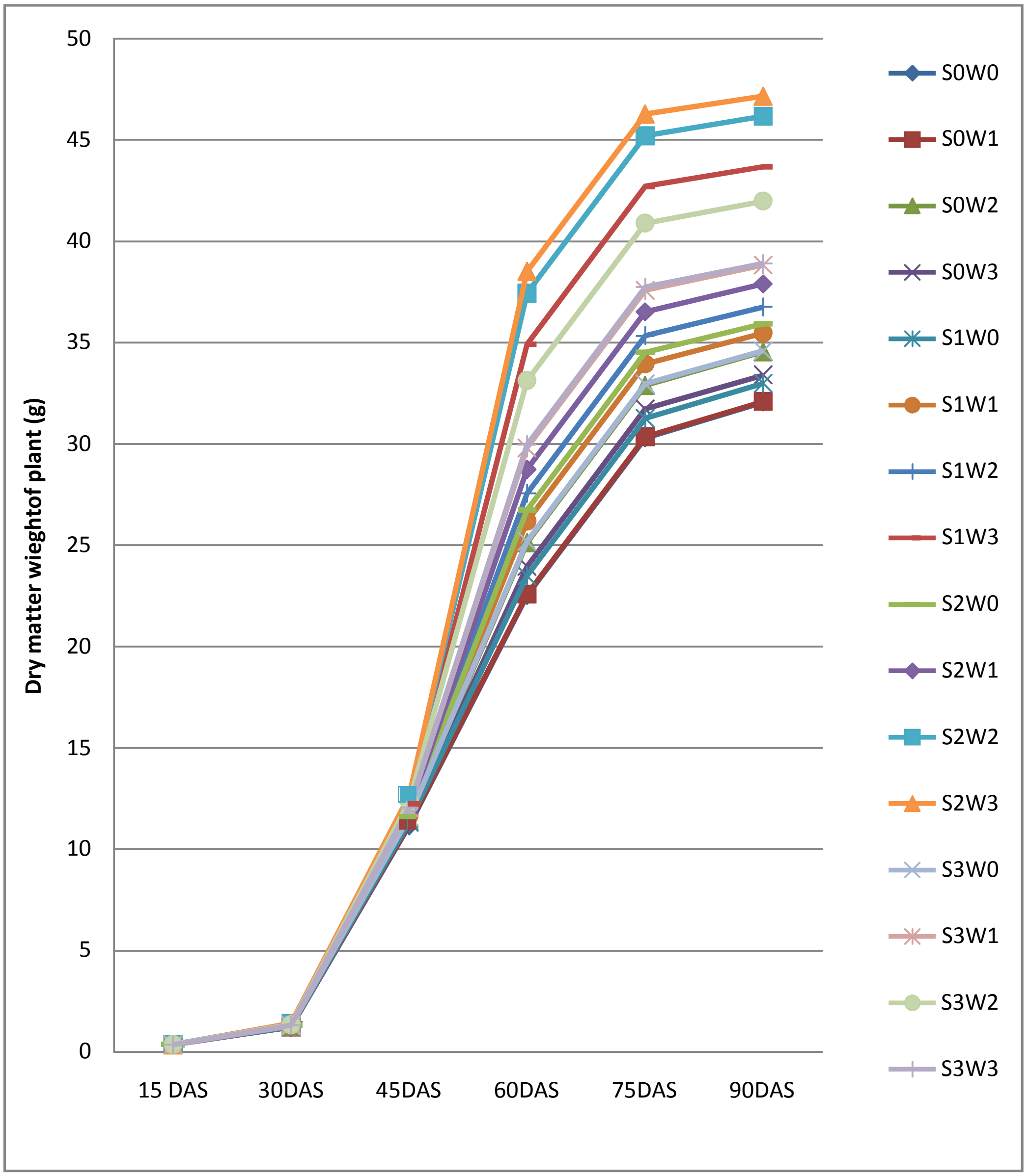
NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

These differences further increased at the successive stages. At 45 DAS the treatment W_3 produced the maximum dry matter which was almost similar with W_2, but significantly different from W_1 and W_0. At 60 DAS, 75 DAS and 90 DAS the highest dry matter accumulation was found from the treatment W_3 which was significantly different from W_2, W_1 and W_0. The W_3 treatment produced tallest plant with highest number of branches which might have contributed in the accumulation of highest dry matter at those three stages. It might be due to maximum plant height and stem thickness in this treatment. The rate of increase in TDM, however, varied depending on growth stage. TDM increased at a slow rate up to 30 DAE. A very sharp rise in TDM production occurred from 30 to 60 DAS and thereafter the rate of increase was comparatively low. Total dry matter showed a declining tendency after 80 DAS.

Interaction effect of sulphur and weeding

The effect of interaction between sulphur and weeding on dry matter production was significantly varied at different stages except 30 DAS (Fig. 2). At 60 DAS the treatment S_2W_3 produced the highest dry matter followed by S_2W_2 and the lowest dry matter was found from the treatment S_0W_1 . The treatment S_2W_3 produced the highest dry matter at 60, 75 and 90 DAS which was followed by the treatment S_2W_2 . The lowest dry matter was found from the treatment S_0W_1 at 60 and 75 DAS and 90 DAS.



S_0 = Control	W_0 =Control
S_1 = 15 kg Sulphur per ha	W_1 =One hand weeding at 15 DAS
S_2 = 30 kg Sulphur per ha	W_2 =Two hand weeding at 15,30 DAS
S_3 = 45 kg Sulphur per ha	W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig 2. Total dry matter weight per plant of rapeseed at different ages as affected by the interaction between sulphur rate and number of weeding at different days after sowing (DAS)

4.3. Dry matter partitioning

Accumulation of dry matter and its partitioning into different plant components is an important consideration in achieving desirable economic yield from the crop plants. The economic yield is greatly determined by the production of total dry matter and its partitioning by the reproductive organ (Singh and Yadav, 1989). Sulphur and weeding exerted significant effect on dry matter accumulation and its partitioning into the components of rapeseed at all stages of crop growth.

Effect of sulphur

Sulphur is an important criterion for dry matter accumulation as it facilitates higher protein synthesis. Dry matter accumulation in leaves was affected by different sulphur dose (Table 5). In this experiment, 100% dry matter was observed in leaves at 30 and 45 DAS as only leaves were prominent in the plant at these stages. At 45 DAS there was no significant effect was found on leaf dry matter weight . Onward 60 and 75 DAS the highest dry matter in leaves was found at treatment S_2 (30 kg /ha), which was almost similar with S_3 but significantly different from the other sulphur treatment. It was followed by S_1 (15 kg/ha) where S_0 produced the lowest leaf dry. At 45 DAS there was an increasing trend of dry matter weight of leaves with increasing the sulphur fertilizer. It this stage more or less 35% of total dry weight was accumulated in leaves with all the treatment (Fig. 3). But at 75 DAS these was at decreasing trend as leaf senescence occurred and at 90 DAS the plants remained in the field without any leaf. At 75 DAS only 5-6% dry matter was accumulated in leaves with all the treatments (Fig. 3).

Table 5. Dry matter weight in leaves per plant of rapeseed at different age as affected by different sulphur dose

Treatments	Days after sowing (DAS)		
	45	**60**	**75**
S0	4.19 b	2.08 c	1.88 c
S1	4.33 ab	2.39 b	2.19 b
S2	4.46 a	2.64 a	2.44 a
S3	4.39 a	2.51 ab	2.31 ab
SX value	**0.03**	**0.03**	**0.03**
CV(%)	**1.03**	**1.85**	**2.02**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

In case of dry matter accumulation in the stem, significant difference was found for all growth stages (Table 6). At 60 DAS 32%, 30%,28% and 26% dry matter was observed to accumulate with the treatment $S_{0,}$ S_1 ,S_2 and S_3 , respectively (Fig. 4.3). Almost similar trend was found at 75 DAS and 90 DAS. Incase of 75 DAS and 90 DAS dry matter weight of stem was lower than that of siliqua dry matter weight with all the treatments. S_2 produced the highest stem dry matter which was statistically identical with S_3 because the plants could get necessary nutrients ascompared to the plants of other treated plot. S_0 produced the lowest dry matter in all the growth stages.

Table 6. Dry matter weight in stem per plant of rapeseed at different age as affected by different sulphur dose

Treatments	Days after sowing (DAS)			
	45	**60**	**75**	**90**
S0	4.016 b	7.680 c	8.293 c	8.627 c
S1	4.219 a	8.173 b	8.787 b	9.120 b
S2	4.368 a	8.563 a	9.177 a	9.510 a
S3	4.340 a	8.427 a	9.040 a	9.373 a
SX value	**0.0341**	**0.0346**	**0.0346**	**0.0346**
CV(%)	**1.06**	**0.54**	**0.51**	**0.49**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Significant dry matter accumulation in reproductive organs (inflorescence) was observed at 45 DAS and accumulation continued till 90 DAS (Table 7). After 45 DAS i.e. during seed development period, leaf dry weight tended to decrease while inflorescence dry weight started to increase. At 45 DAS near about 28% dry matter weight of inflorescence was recorded with all the treatment which was lower than stem dry matter weight. But at 60 DAS 58%, 62% , 64% and 63% dry matter weights of inflorescence was recorded with S_0 (control), S_1 (15 kg/ha) , S_2 (30 kg/ha) and S_3 (45 kg/ha) (Fig. 3). The decrease in leaf dry weights during seed development stage might be attributed to remobilization of stored assimilates from the vegetative organs to the reproductive ones.

Table 7. Dry matter weight in inflorescence per plant of rapeseed at differen age as affected by different sulphur rate

Treatments	Days after sowing (DAS)			
	45	60	75	90
S0	3.09 c	13.78 d	21.13 d	24.40 d
S1	3.20 bc	17.47 c	24.83 c	28.10 c
S2	3.37 a	21.66 a	29.01 a	32.28 a
S3	3.27 ab	18.58 b	25.93 b	29.20 b
SX value	**0.036**	**0.10**	**0.10**	**0.10**
CV(%)	**1.69**	**2.40**	**1.70**	**1.51**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

From 75 DAS onwards, the major portion of TDM was accumulated in reproductive organs i.e. siliqua. Thus the contribution of inflorescence dry weight to TDM weight increased to a great extent. At 90 DAS maximum dry matter weight in inflorescence was found. Significant variation was found in dry matter accumulation in inflorescence at different growth stages in rapeseed at different sulphur rate. At S_2 highest dry matter accumulation was found at all the growth stages which were statistically different from the other treatments. At this stage the plant could get adequate nutrient to produce highest number of siliqua with highest dry matter. At S_0 (control) the shortage of sulphur fertilizer and higher competition for nutrient reduced the dry matter accumulation in siliqua. Sulphur is mainly responsible for enhancing the reproductive growth and the proportion of the reproductive tissues (inflorescences and pods) in total dry matter (McGrath and Zhao, 1996). The application of S at 30 kg S ha^{-1} was reported to be most suitable and appropriate dose for increasing rapeseed and mustard yield in S deficient soils (Malhi and Gill, 2002; Subhani *et al.*, 2003; Hedge and Murthy, 2005; Tiwari and Gupta, 2006).

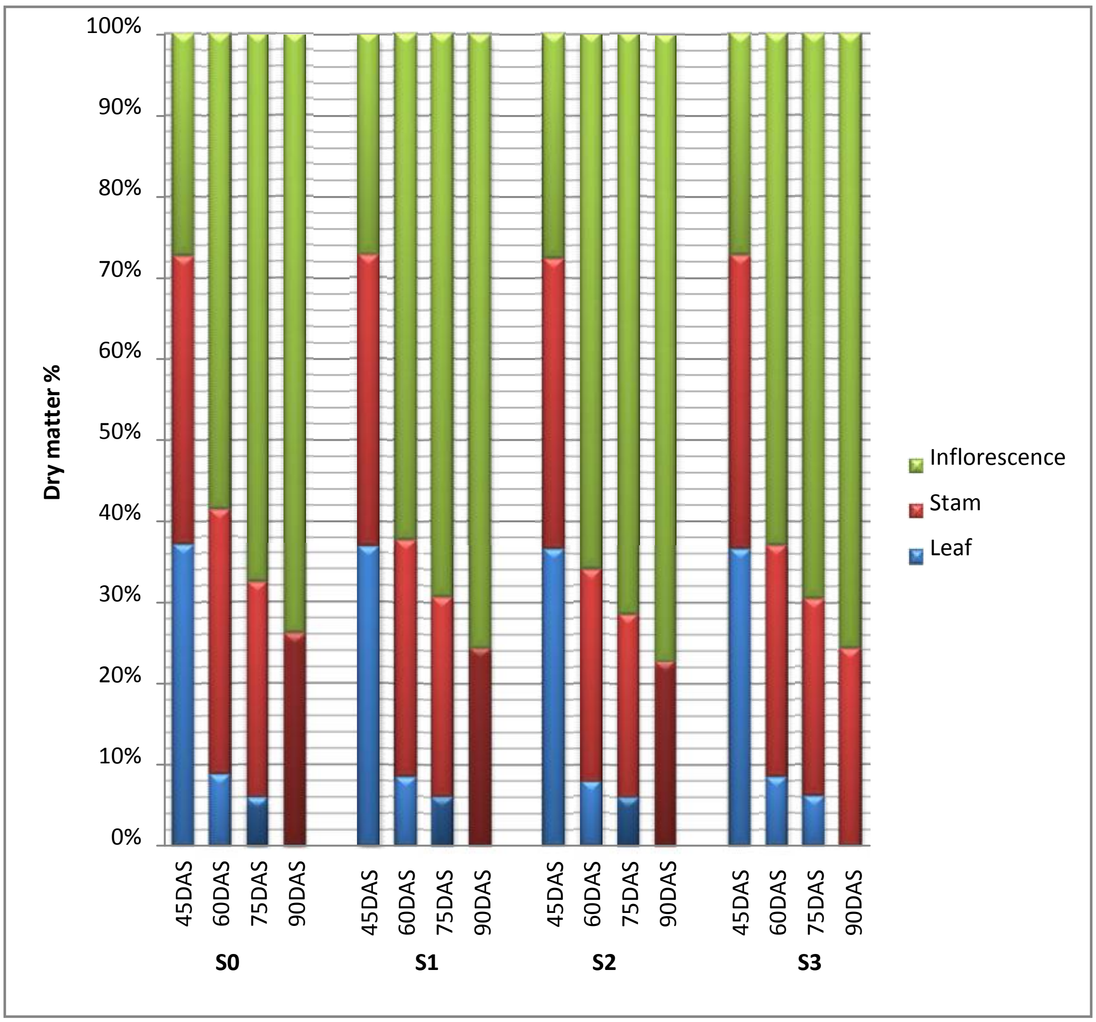


Fig. 3. Dry matter accumulation in different parts of rapeseed at different ages as affected by different rate of sulphur

Effect of weeding

Weeding showed significant difference in leaf dry matter production at different growth stages. At 45 DAS there was no significant difference in leaf dry weight among the treatments. At 45 DAS near about 38% dry weight of leaves was found in all the treatment (Fig. 4). At 60 DAS siliqua dry matter weight was more than stem dry matter weight for all treatments. The treatment W_2 produced the highest leaf and stem dry matter both at 60 and 75 DAS and it was followed by W_3 and lowest dry matter was produced under control condition (No weeding). A tremendous decreasing trend was found in leaf dry matter production with the increase of growth stage (Table 8). The dry matter of leaf at 75 DAS was much lower than the dry matter at 45 DAS and it might be due to the leaf defoliation.

Table 8. Dry matter weight in leaves per plant of rapeseed at different age as affected by different weeding treatment

Treatments	Days after sowing (DAS)		
	45	60	75
W_0	4.243 b	2.169 c	1.969 c
W_1	4.325 ab	2.328 b	2.128 b
W_2	4.398 a	2.520 a	2.320 a
W_3	4.425 a	2.626 a	2.426 a
SX value	**0.025**	**0.033**	**0.033**
CV (%)	**0.60**	**1.93**	**2.11**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control

W_1 = One hand weeding at 15 DAS

W_2 = Two hand weeding at15DAS and 30 DAS

W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

An increasing trend was found in stem dry matter weight production at different growth stages with increase in the number of weeding (Table 4.9). A significant variation was found among the different weeding treatment where W_2 produced the highest dry matter at all the stages and it was followed by W_3. The lowest dry matter weight was accumulated with no weeding which indicated that weeding was needed for dry matter weight production in rapeseed.

Table 9. Dry matter weight in stem per plant of rapeseed at different age as affected by different weeding treatment

Treatments	Days after sowing (DAS)			
	45	60	75	90
W0	4.086 b	7.863 c	8.477 c	8.810 c
W1	4.213 ab	8.127 b	8.741 b	9.074 b
W2	4.318 a	8.376 a	8.989 a	9.323 a
W3	4.327 a	8.477 a	9.090 a	9.423 a
SX value	**0.028**	**0.031**	**0.031**	**0.031**
CV (%)	**0.81**	**0.51**	**0.48**	**0.46**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Weeding facilitated to lower competition for nutrient and space and have maximum stem thickness and branching rendering more dry matter accumulation in this organ. At 60 DAS stem dry matter weight accumulation percentages was high. But at maturity stage (90 DAS) stem dry matter weight was lower than siliqua dry matter weight even than dry mater weight of stem found at 75 DAS (Fig. 4).

Table 10. Dry matter weight in inflorescence per plant of rapeseed at different age as affected by different weeding treatment

Treatments	Days after sowing (DAS)			
	45	60	75	90
W_0	3.112 b	14.46 d	21.81 d	25.08 d
W_1	3.150 b	16.37 c	23.73 c	27.00 c
W_2	3.349 a	19.92 b	27.27 b	30.54 b
W_3	3.338 a	20.74 a	28.10 a	31.36 a
SX value	**0.030**	**0.115**	**0.115**	**0.115**
CV (%)	**0.81**	**0.51**	**0.48**	**0.46**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

A significant difference was found in case of dry matter accumulation in inflorescence at different times with different weeding operation (Table 10). At every stage, maximum dry weight of inflorescence was found with three hand weeding at 15, 30 and 45 DAS while W_0 treatment (control) produced the lowest dry weight of inflorescence. At 45 DAS 28% dry mater was recorded in inflorescence with almost all the treatment. The same trend was found at later stages but the rate was slower (Fig. 4). At W_3 there was no competition of soil moisture and nutrients at all the stages, as a result dry matter accumulation was higher than those of other treatment.

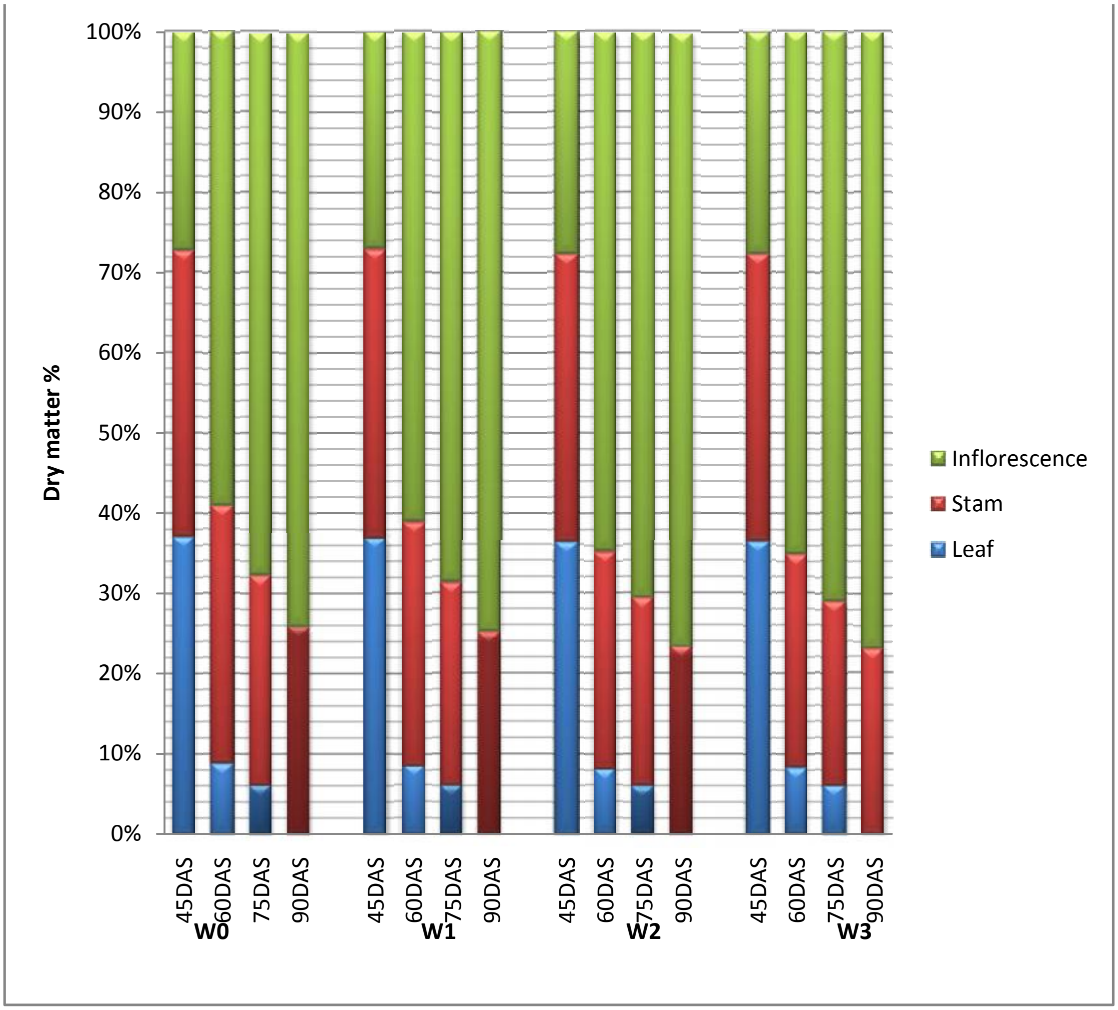
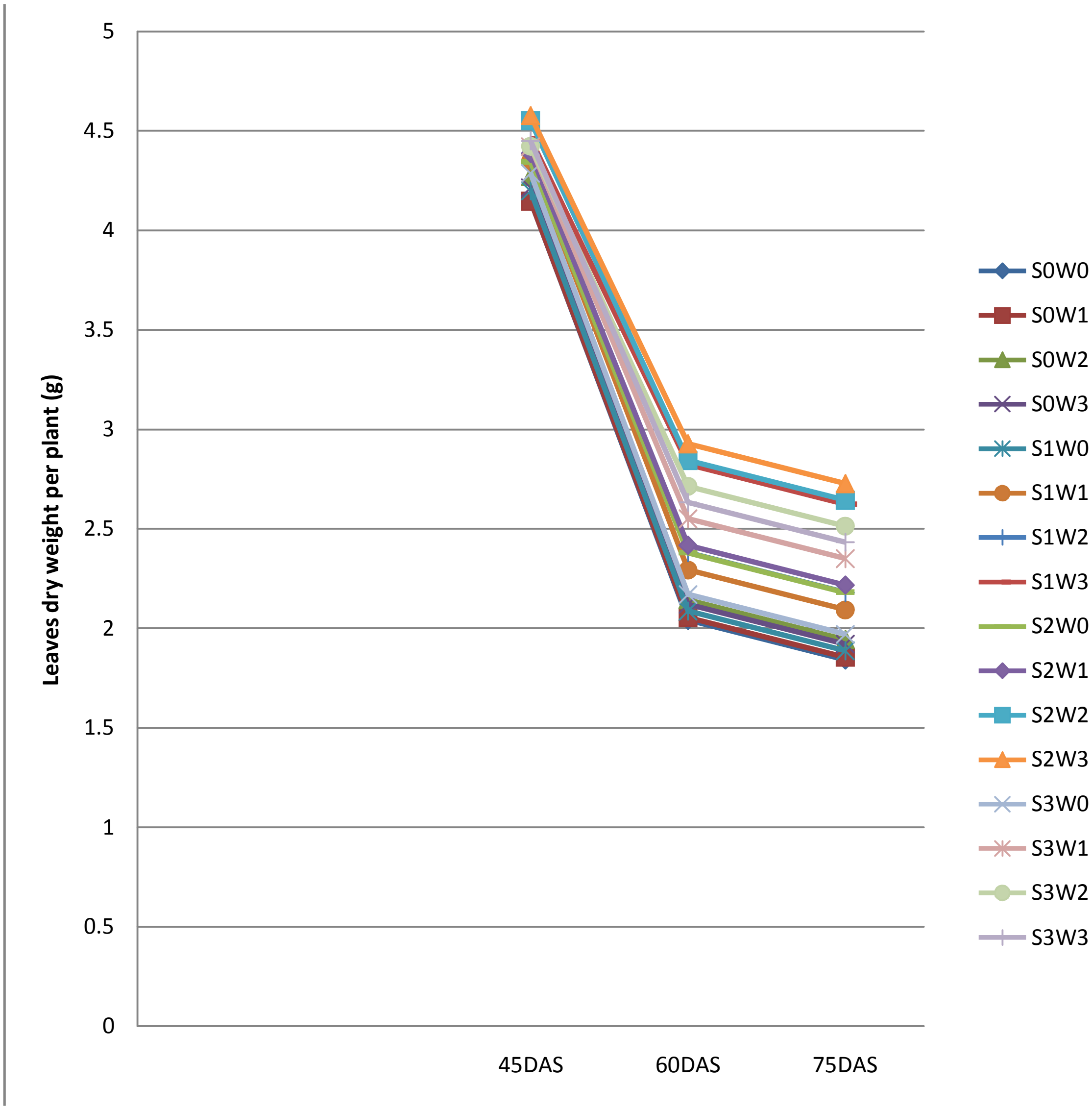


Fig. 4. Dry matter accumulation in different parts of rapeseed at different ages as affected by different weeding operation

Interaction effect sulphur and weeding

Interaction between sulphur and weeding showed significant variation in dry matter accumulation in leaves, stem and siliqua. In case of dry matter accumulation in leaves, the treatment. S_2W_3 showed the highest at 60 and 75 DAS which was followed by S_2W_2 (Fig. 5). At both the stages the treatment S_0W_0 and S_0W_1 produced the lowest dry matter in leaves.



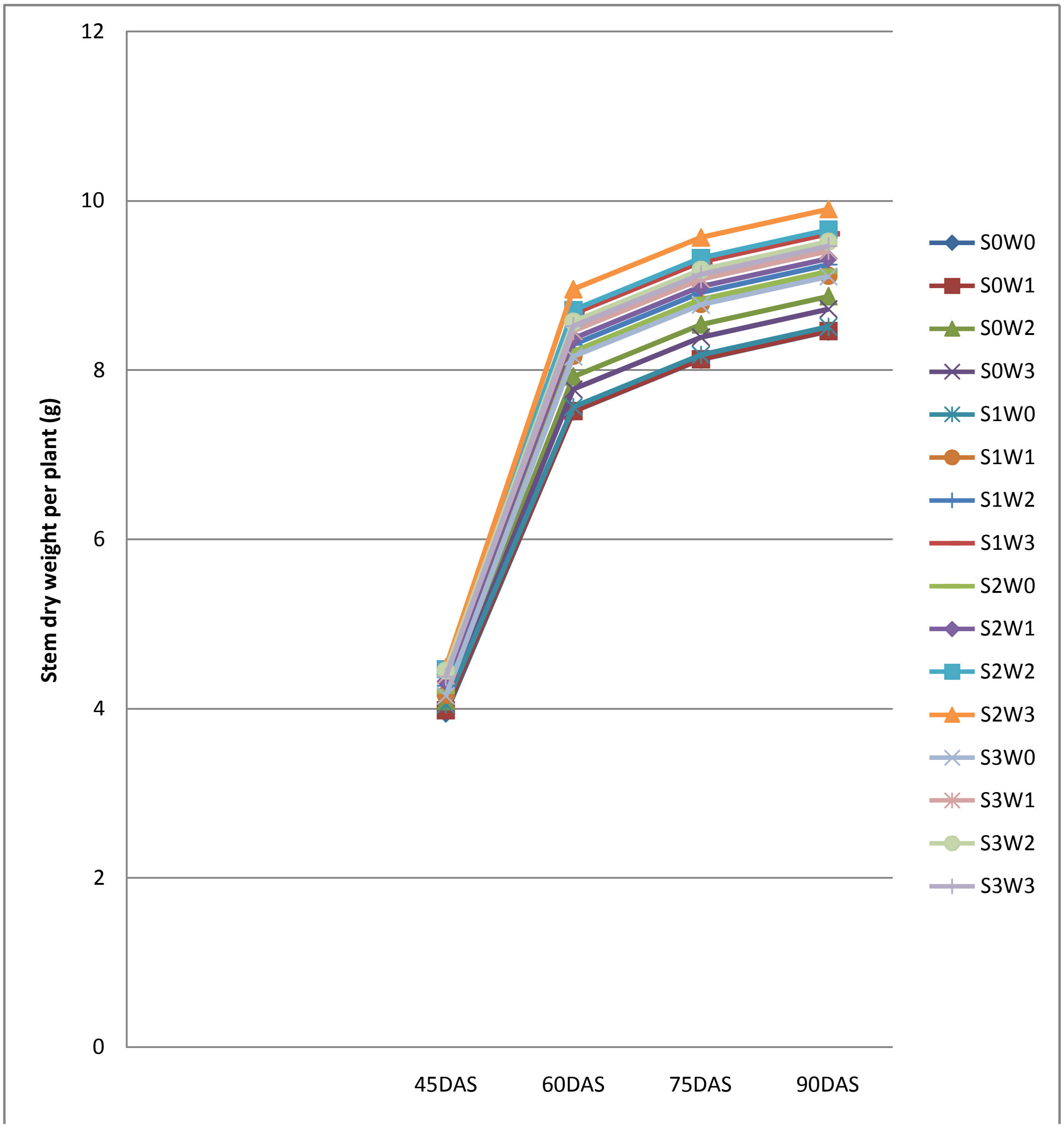
S_0 = Control W_0 =Control

S_1 = 15 kg Sulphur per ha W_1 =One hand weeding at 15 DAS

S_2 = 30 kg Sulphur per ha W_2 =Two hand weeding at 15,30 DAS

S_3 = 45 kg Sulphur per ha W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig. 5. Dry matter weight of leaves of rapeseed at different ages as affected by the interaction between sulphur and weeding at different days after sowing (DAS)



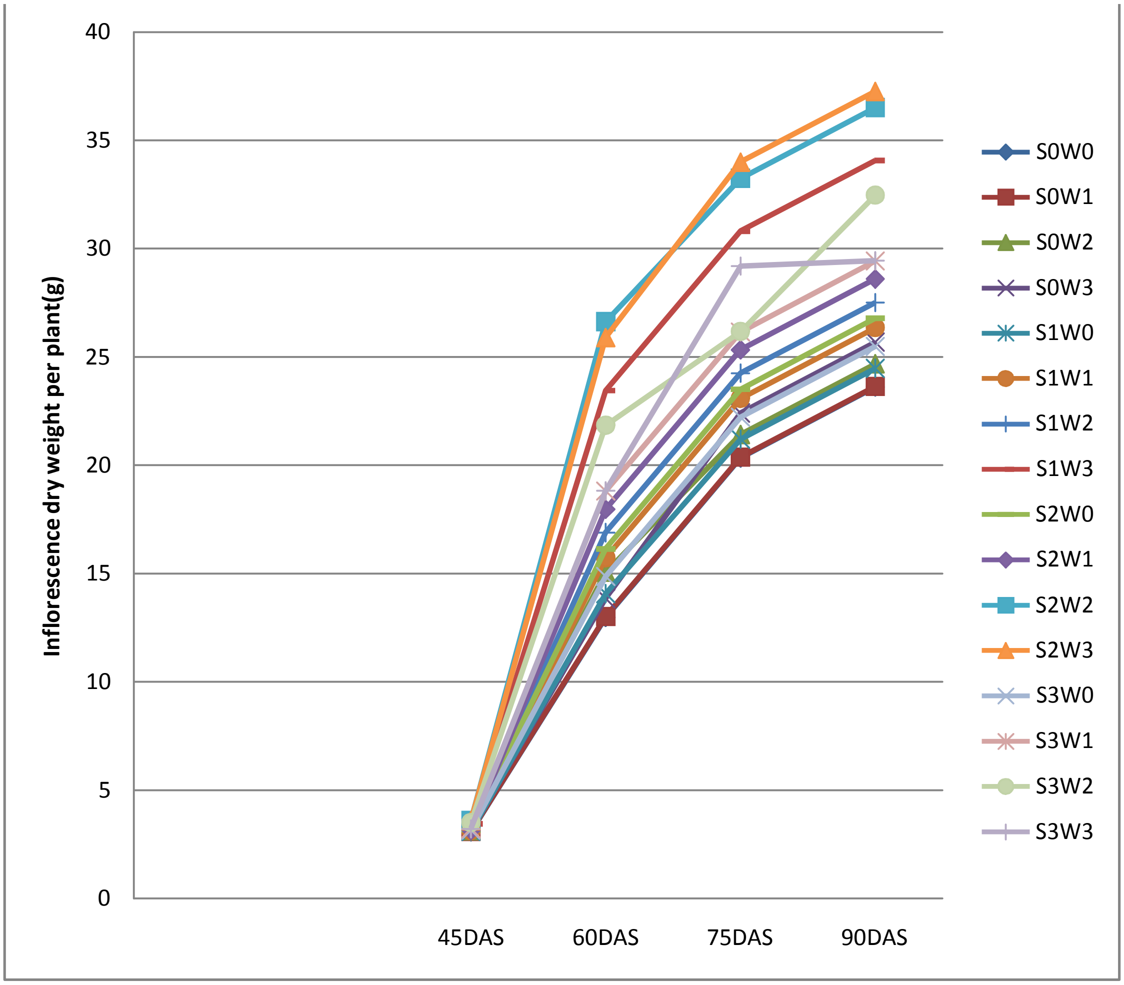
S_0 = Control W_0 =Control

S_1 = 15 kg Sulphur per ha W_1 =One hand weeding at 15 DAS

S_2 = 30 kg Sulphur per ha W_2 =Two hand weeding at 15,30 DAS

S_3 = 45 kg Sulphur per ha W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig. 6. Dry matter weight of stem of rapeseed at different ages as affected by the interaction between sulphur and weeding at different days after sowing (DAS)



S_0 = Control	W_0 =Control
S_1 = 15 kg Sulphur per ha	W_1 =One hand weeding at 15 DAS
S_2 = 30 kg Sulphur per ha	W_2 =Two hand weeding at 15,30 DAS
S_3 = 45 kg Sulphur per ha	W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig. 7. Dry matter weight of inflorescence of rapeseed at different ages as affected by the interaction between sulphur and weeding

In stem the treatment S_2W_3 produced the highest dry matter in all the stages except 45 DAS. In case of 45 DAS variation for third weeding was not created and that was why S_2W_2 produced highest dry matter in stem at this stage. At 75 DAS the second highest dry matter was produced with S_2W_2 . In case of 90 DAS, the second highest dry matter was produced in S_2W_2 (Fig. 6).

Like dry matter in leaves and in stem significant interaction effect was found for dry matter accumulation in inflorescence per plant (Fig. 7). The treatment S_2W_3 produced the highest dry matter in inflorescence which was followed by S_2W_2 for all the growth stages (60, 75 and 90 DAS). In this treatment three weeding provided favourable soil moisture as less competition and S_2 (30 kg S/ha) provided the maximum availability of nutrients for plant growth and development for the reproductive organs which might be the reason of accumulating highest dry matter from the treatment S_2W_3.

4.4.Leaf area

Effect of Sulphur

Sulphur caused significant variation in leaf area of rapeseed (Table 11). Leaf area increased with increasing level of sulphur up to 30 kg/ha at all growth stages.The application of sulphur @30kg/ha ultimately produced the higher leaf area than S_0 (control), S_1 (15 kg/ha) and S3 (45 kg/ha). The increase in leaf area with the application of sulphur is attributed to have favorable effect on chlorophyll synthesis resulting in more number of leaves with bigger size and higher chlorophyll content the significant increases in leaf area index in mustard were also recorded by Patel and Shelke (1998).

Table 11. Leaf area per plant of rapeseed at different age as affected by different sulphur dose

Treatments	Days after sowing (DAS)				
	15	**30**	**45**	**60**	**75**
S0	20.86 d	108.4 d	163.0 d	217.8 d	245.7 d
S1	21.84 c	117.6 c	179.1 c	234.5 c	262.4 c
S2	23.20 a	123.9 a	189.7 a	243.8 a	271.7 a
S3	22.52 b	122.0 b	186.4 b	241.4 b	269.3 b
SX value	**0.072**	**0.112**	**0.159**	**0.163**	**0.163**
CV(%)	**0.97**	**0.45**	**0.59**	**0.47**	**0.42**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.
S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Effect of Weeding

Significant variation was found in leaf area per plant with the time among the different weeding treatments in all growth stages (Table 12). These differences further increased at the successive stages. At 15 DAS the treatment W_3 produced the maximum leaf area which was almost similar with $W_{2,}$ but significantly different from W_1 and W_0. At 30DAS, 45DAS,60 DAS, 75 DAS and 90 DAS the highest leaf area was found from the treatment W_3 which was significantly different from W_2, W_1 and W_0. The W_3 treatment produced tallest plant with highest number of bigger leaf which might have contributed for the maximum leaf area at those stages.

Table 12. Leaf area per plant of rapeseed at different age as affected by different weeding treatment

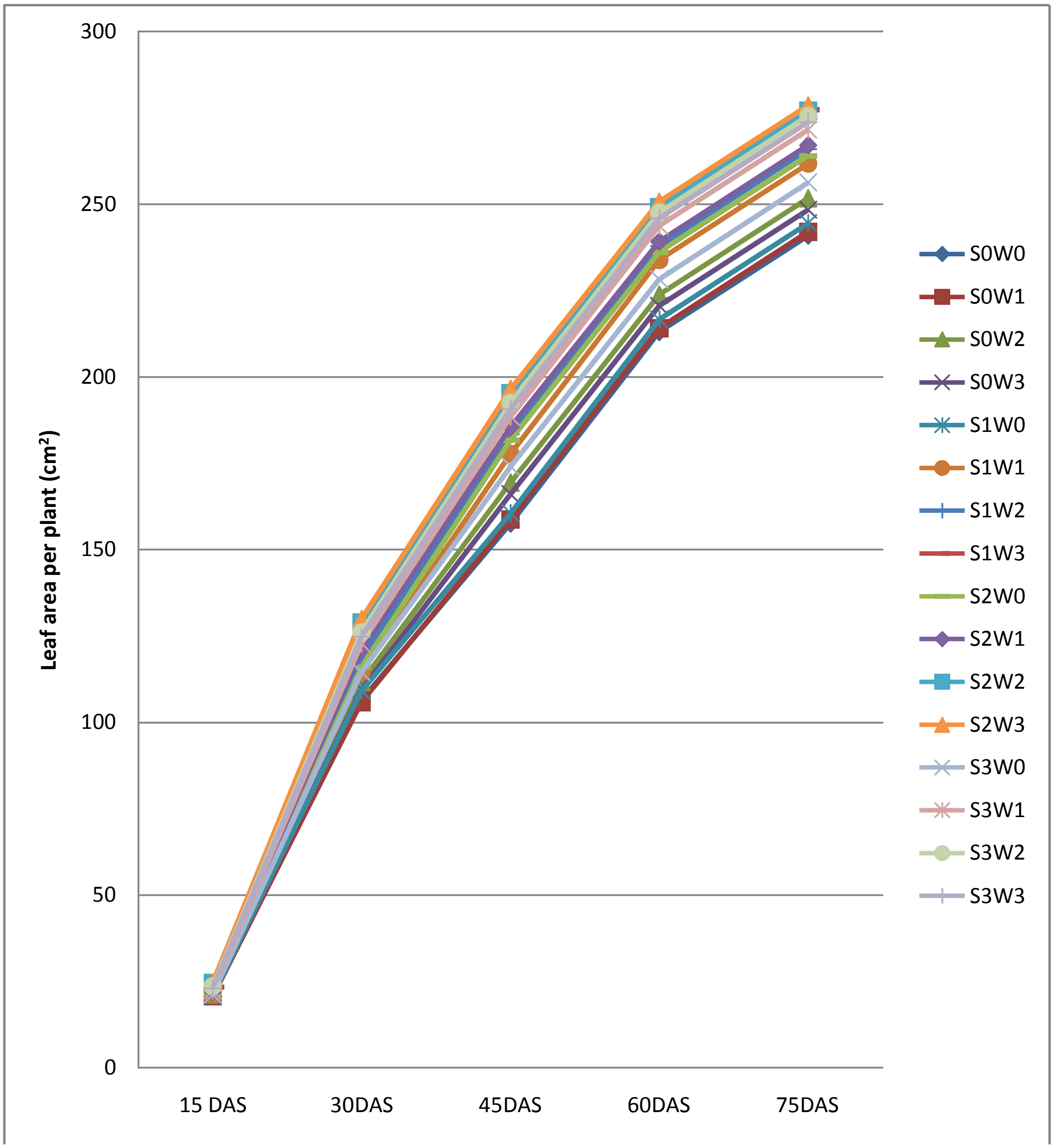
Treatments	Days after sowing (DAS)				
	15	**30**	**45**	**60**	**75**
W0	21.08 c	111.5 d	168.5 d	223.5 d	251.4 d
W1	21.63 b	116.1 c	177.6 c	232.7 c	260.6 c
W2	22.76 a	121.3 b	185.1 b	239.6 b	267.5 b
W3	22.96 a	123.0 a	187.1 a	241.6 a	269.6 a
SX value	**0.086**	**0.121**	**0.184**	**0.184**	**0.184**
CV (%)	**1.41**	**0.52**	**0.79**	**0.60**	**0.54**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Interaction effect of sulphur rate and weeding

The effect of interaction between sulphur and weeding on leaf area production was significantly varied at different stages except 15 DAS (Fig. 8). At 60 DAS the treatment S_2W_3 produced the highest leaf area followed by S_2W_2 and the lowest leaf area was found from the treatment S_0W_1 . The treatment S_2W_3 produced the highest leaf area at 60, 75 and 90 DAS which was followed by the treatment S_2W_2 . The lowest leaf area was found from the treatment S_0W_1 and S_0W_1 at 60 and 75 DAS and 90 DAS.



S_0 = Control W_0 =Control

S_1 = 15 kg Sulphur per ha W_1 =One hand weeding at 15 DAS

S_2 = 30 kg Sulphur per ha W_2 =Two hand weeding at 15,30 DAS

S_3 = 45 kg Sulphur per ha W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig. 8. Leaf area per plant of rapeseed at different ages as affected by the interaction between sulphur and weeding

4.5. Weed dry matter weight

Effect of sulphur

Sulphur rate had no significant variation in weed dry matter production (Table 13) Among the sulphur rate S_3 produced the comparatively lower weed dry matter at all growth stages .It might be due to the competition between vigorous rapeseed plant in S_3 treated plots.

Table 13. Weed dry matter weight per square meter of rapeseed fields at different age as affected by different sulphur treatment

Treatments	Days after sowing (DAS)					
	20	**35**	**50**	**65**	**80**	**After harvest**
S0	0.450	1.519 ab	5.895 b	14.79 a	18.00 a	19.84 a
S1	0.476	1.548 ab	5.958 ab	14.90 a	18.16 a	20.02 a
S2	0.488	1.655 a	6.107 a	15.02 a	18.26 a	20.11 a
S3	0.454	1.458 b	5.892 b	13.90 b	17.18 b	19.01 b
SX value	**0.028**	**0.033**	**0.037**	**0.066**	**0.066**	**0.066**
CV(%)	**6.76**	**2.89**	**1.06**	**1.26**	**1.03**	**0.93**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Effect of weeding

Significant variation was found in weed dry matter per square meter with the time among the different weeding treatments in all growth stages (Table 14). These differences further increased at the successive stages. At 20 DAS only the treatment W_0 produced the weed but all other treated plots had no weed because weeding operation was done just before 20 DAS in those plots. Similar occurrence was found at 35 and 50 DAS in W_1, W_2 and W_3 respectively. The W_0 treatment produced highest weed biomass at all stages due to the growth of weed without any disturbance. Among the treatments W_3 produced lower weed biomass which was significantly lowest with other treatment (Table 14).

Table 14. Weed dry matter weight per square meter of rapeseed fields at different age as affected by different weeding treatment

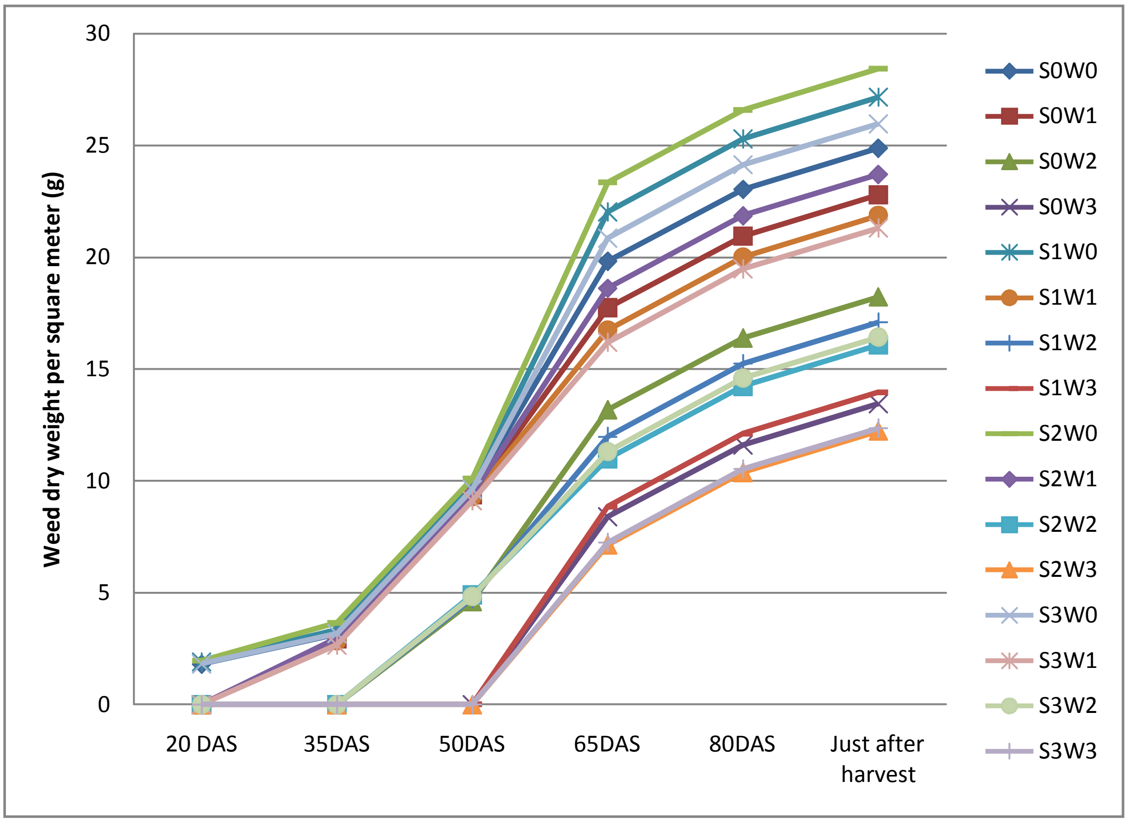
Treatments	Days after sowing (DAS)					
	20	**35**	**50**	**65**	**80**	**After harvest**
W0	1.870 a	3.327 a	9.777 a	21.52 a	24.76 a	26.61 a
W1	0.000 b	2.854 b	9.304 b	17.33 b	20.57 b	22.42 b
W2	0.000 b	0.000 c	4.771 c	11.87 c	15.11 c	16.96 c
W3	0.000 b	0.000 c	0.000 d	7.910 d	11.16 d	13.00 d
SX value	**0.027**	**0.036**	**0.038**	**0.096**	**0.096**	**0.096**
CV (%)	**6.58**	**3.59**	**1.03**	**2.64**	**2.16**	**1.96**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Interaction effect of sulphur rate and weeding

The effect of interaction between sulphur and weeding on weed biomass production was significantly varied at different stages (Fig. 9). At 65 DAS the treatment S_2W_3 produced the lowest weed biomass followed by S_0W_3 and S_1W_3 and the highest amount of weed was found from the treatment S_2W_0. This result was also found in later stages.



S_0 = Control W_0 =Control
S_1 = 15 kg Sulphur per ha W_1 =One hand weeding at 15 DAS
S_2 = 30 kg Sulphur per ha W_2 =Two hand weeding at 15,30 DAS
S_3 = 45 kg Sulphur per ha W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig. 9. Weed dry matter weight per square meter of rapeseed fields at different ages as affected by the interaction between sulphur and weeding

4.6. Yield attributes

4.6.1. Number of branch per plant

Number of branches per plant is the result of genetic makeup of the plant and environmental conditions, which plays a remarkable role towards the final seed yield of the crop (Sana *et al.*, 2003). Number of branches per plant is an important factor which affects the yield per plant and in this study it indicated that the number of branches per plant varied significantly with different treatment .

Effect of sulphur

Number of branches per plant was significantly influenced by sulphur (Table 15). Lower application of sulphur significantly decreased the number of branches per plant. Significantly highest number of branches per plant was found in the application of sulphur @ 30kg/ha which was significantly identical with S_3 (45 kg S /ha) and the lowest from the control. Reduced number of branches per plant was due to the scarcity of nutrients. Increase in number of branches of plant up to 45 kg S/ha may be due to enhanced photosynthesis, as sulphur is moved in the formation of chlorophyll and activation of enzymes. Similar results were also reported by Rana *et al*. (2001), Khanpara *et al*. (1993), Sharma (1994) and Chauhan *et al*. (1996).

Table 15. Number of branches per plant of rapeseed at different age as affected by sulphur dose

Treatments	Days after sowing (DAS)			
	45	60	75	90
S0	3.358 c	5.083 c	4.933 c	5.133 c
S1	3.817 b	5.867 b	5.867 b	6.067 b
S2	4.233 a	6.367 a	6.533 a	6.733 a
S3	4.050 a	6.050 b	6.350 a	6.550 a
SX value	**0.048**	**0.059**	**0.046**	**0.046**
CV(%)	**2.59**	**2.48**	**1.51**	**1.46**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.
S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Effect of weeding

From the study it was found that weeding has great influence on the number of branches per plant in rapeseed (Table 16). Number of weeding significantly increased the number of branches per plant. The maximum numbers of branches were found from W_2 and W_3. The lowest numbers of branches were found from control treatment. Weeding facilitates the plants to have more resources which render increased plant height and also more number of branches per plant in this experiment. This result corroborated with the findings of Gaffer, (1984).

Table 16. Number of branches per plant of rapeseed at different age as affected by number of weeding

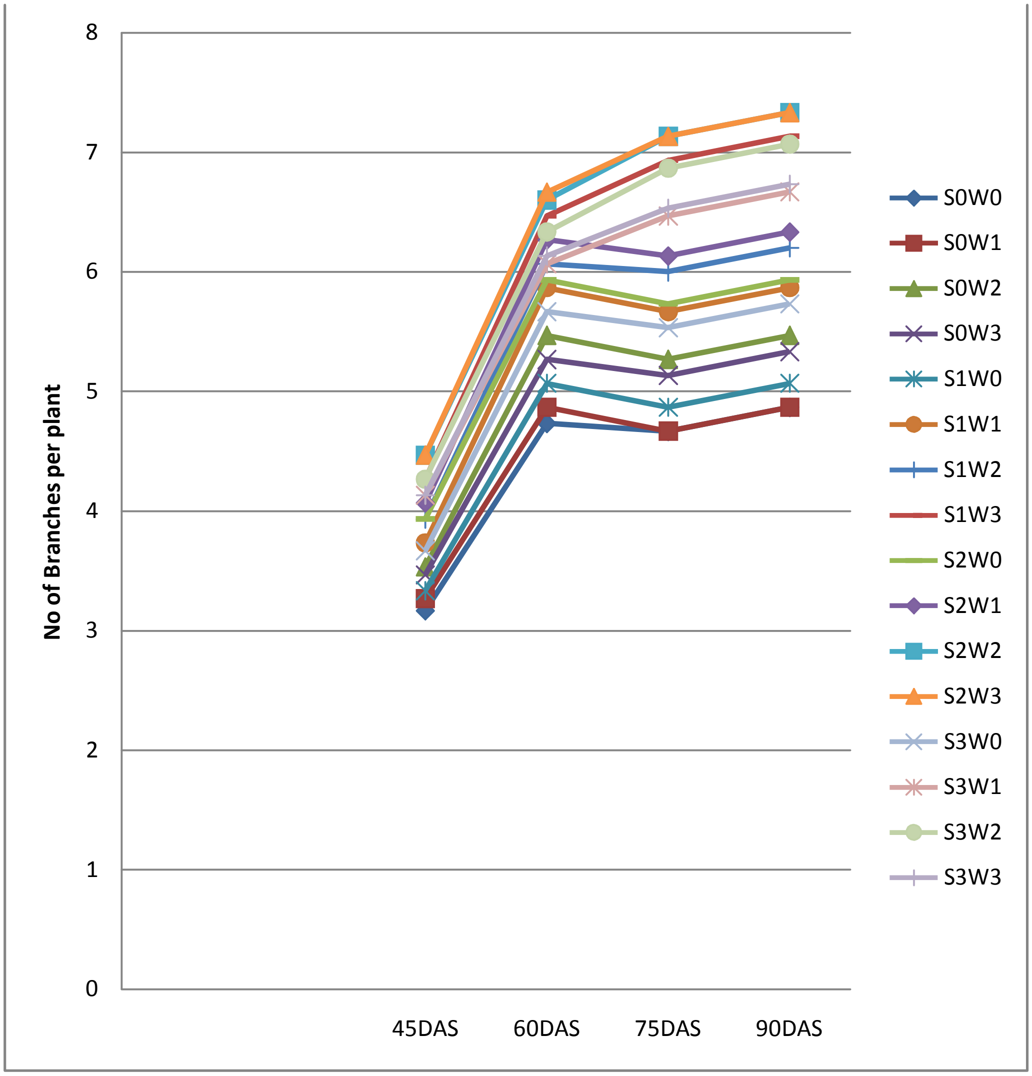
Treatments	Days after sowing (DAS)			
	45	60	75	90
W0	3.525 c	5.350 c	5.200 c	5.400 c
W1	3.800 b	5.767 b	5.733 b	5.933 b
W2	4.050 a	6.117 a	6.317 a	6.517 a
W3	4.083 a	6.133 a	6.433 a	6.633 a
SX value	**0.05315**	**0.05000**	**0.05642**	**0.05642**
CV (%)	**3.04**	**1.78**	**2.23**	**2.16**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Interaction effect of sulphur rate and weeding

In the rapeseed the numbers of branches per plant were significantly increased by the interaction effect of sulphur rate and weeding (Fig.10). In the study the maximum number of branches per plant was found from the interaction between two and three weeding with the application of sulphur @ 30 kg/ha. The least number of branches were found from the interaction between S_0 (control) with W_0 and W_1. It revealed that sulphur upto 45 kg/ha with two and three weeding produced higher number of branches per plant of rapeseed.



S_0 = Control	W_0 =Control
S_1 = 15 kg Sulphur per ha	W_1 =One hand weeding at 15 DAS
S_2 = 30 kg Sulphur per ha	W_2 =Two hand weeding at 15,30 DAS
S_3 = 45 kg Sulphur per ha	W_3 =Three hand weeding at 15, 30 and 45 DAS

Fig. 10. Number of branches per plant of rapeseed at different ages as affected by the interaction between sulphur and weeding

4.6.2. Number of siliquae per plant

Number of siliquae per plant is the result of genetic make up of the crop and environmental conditions (Sana *et al*., 2003). It is an important yield contributing character which has a great effect on final yield.

Effect of sulphur

Significant difference was found in number of siliquae per plant at different sulphur dose. The highest number of siliquae per plant (71.26) was recorded at S_2 (30 kg S/ha) and the lowest (53.63) at S_0 (control) with a difference of 7.52%. Number of siliquae plant^{-1} directly correlates with dry matter production by the plants. The treatment S_0 produced the lowest number of siliquae per plant, because scarcity of sulphur. Sulphur is mainly responsible for enhancing the reproductive growth and the proportion of the reproductive tissues (inflorescences and pods) in total dry matter (McGrath and Zhao, 1996).

Effect of weeding

Number of siliquae is an important factor for increasing yield, which is adversely affected by weeding. Weeding facilitates the plants to have more resources rendering increase in reproductive organ and more number of siliquae per plant in this experiment. So weeding plays an important role in increasing the yield and yield attributes. In the present study, number of weeding showed significant variation in producing siliquae plant^{-1} (Table 18). Among the treatment W_2 produced the highest number of siliquae (67.09) which was statistically identical with W_3 (66.71) and statistically different from W_1 (64.42) and W_0 (58.88).

The treatment W_0 which received no weeding throughout the life cycle thus produced the lowest number of siliqua. In case of W_2 and W_3 the plant were free from weed at siliqua formation stage which helped in producing more number of siliqua. But in case of treatment W_0 there was more number of weed and thus more competition for resources (nutrients, soil moisture etc) and due to insufficient soil moisture and nutrients reduced the number of siliquae per plant.

Interaction effect of sulphur and weeding

Favourable moisture regimes influenced plant to produce more biomass, which eventually portioned to siliqua. Significant difference was found due to the interaction of sulphur and weeding (Table 19). Any interaction of sulphur application except control with two or three times weeding provided more number of seeds per plant than others. 30 kg sulphur /ha with two times weeding (S_2W_2) produced the highest number of siliquae per plant (72.06) which was statistically identical with similar sulphur dose with at least one weeding operation. The lowest number of siliquae (52.23) was found from the treatment S_0W_0 and S_0W_1.

4.6.3 Number of seeds per siliqua

Number of seeds per siliqua is also an important factor which contributes towards seed yield. Sulphur rate as well as weeding had a significant effect on the number of seeds siliqua^{-1} in this study.

Effect of sulphur

Number of seeds per siliqua varied significantly with the variation in sulphur application. It evident that the number of seeds per siliqua significantly increase with the increase of sulphur rate upto 30 kg/ha (Table 17). On an average, the highest number of seeds per siliqua (20.25) was recorded from the sulphur application @ 30 kg/ha(S2) followed by 45kg/ha (S3) which was statistically different from the seeds per siliqua found from S_0 and S_1. The lowest number of seeds per siliqua (17.45) was found from the control treatment.

Effect of weeding

Number of seeds per siliqua were significantly affected by number of weeding in this experiment. The number of seeds per siliqua was increased with the increase in weeding number (Table 18). The significantly highest number of seeds (19.92) was found with three times weeding at 15 DAS,30 DAS and 45 DAS while the lowest number of seed per siliqua (18.01) was found from the control treatment. Seed per siliqua increased with increasing number of weeding due to the supply of adequate soil moisture and nutrients which helped formation of long siliqua and more number of seeds.

Interaction effect of sulphur and weeding

Sulphur as well as weeding interact each other to produce seeds per siliqua in rapeseed. Significant variations in the number of seeds per siliqua were found with the different treatments (Table 19). The highest number of seeds per siliqua (21.06) was found from S_2W_3 which was statistically identical with S_3W_3 (20.77). The lowest numbers of seeds per siliqua (16.67) were found from the treatment S_0W_0 which was statistically identical with S_0W_1 . It revealed that weeding had contributed more in the formation of seed in the siliqua of sulphur treated plant. The increasing demand of moisture and nutrients for siliqua setting was fulfilled in the plots provided by icreasing sulphur fertilizer with three times weeding.

Table 17. Yield attributes of rapeseed as affected by sulphur dose

Treatments	No of siliquae per plant	No of seeds per siliqua	No of seeds per plant	1000 seeds weight
S0	53.63 d	17.45 d	936.3 d	2.764 c
S1	64.36 c	19.15 c	1240. c	2.882 b
S2	71.26 a	20.25 a	1443. a	2.984 a
S3	68.84 b	19.77 b	1364. b	2.957 a
SX value	**0.171**	**0.048**	**0.251**	**0.013**
CV(%)	**1.89**	**0.52**	**1.88**	**1.76**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control

S_1 = 15 kg Sulphur per ha

S_2 = 30 kg Sulphur per ha

S_3 = 45 kg Sulphur per ha

4.6.4 Number of seeds per plant

The number of seeds per plant contributes materially towards the final seed yield in rapeseed and it was affected by sulphur dose and weeding in this study.

Effect of sulphur

Sulphur also affected the number of seeds per plant significantly in this study (Table 17). Number of seeds per plant was greatly increased with the increase of sulphur upto 30 kg/ha. Sulphur application@30 kg /ha (S_2) provided the highest number of seed per plant (1443) which was followed by S_3. The number of seeds was found to be lowest (936.3) with control treatment (S_0). The lower application of sulphur, lower was the number of seeds per plant. It might be due to less number of siliqua per plant as well as less number seeds per siliqua for sulphur scarcity subjected to maximum competition, which affected the siliqua fertility.

Table 18. Yield attributes of rapeseed as affected by number of weeding

Treatments	No of siliqua per plant	No of seeds per siliqua	No of seeds per plant	1000 seeds weight(g)
W0	59.88 c	18.01 c	1085.d	2.801 c
W1	64.42 b	18.94 b	1229.c	2.869 bc
W2	67.09 a	19.75 a	1331.b	2.942 ab
W3	66.71 a	19.92 a	1338.a	2.976 a
SX value	**0.199**	**0.050**	**0.108**	**0.023**
CV (%)	**2.57**	**0.55**	**2.26**	**0.77**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Effect of weeding

Weeding is an important factor, which facilitates the use of plant nutrition, air and space to promote the seed yield of rapeseed. Weeding significantly increased the number of siliqua per plant and seeds per siliqua (Table 18). The highest number of seeds per plant 1338) was found from W_3 because weeding created favourable conditions to develop siliqua and seeds. The lowest number of seeds per plant (1085) was found with unweeded control. The reason for the maximum number of seeds $plant^{-1}$ with tree times weeding might be due to adequate soil moisture and nutrients at flowering and seed filling stage as weeding facilitated less competition with resources.

Interaction effect of sulphur rate and weeding

In the study, the interaction of sulphur and weeding had also a great influence on the number of seeds per plant. (Table 19). The highest number of seeds (1508) were found with the interaction of 30 kg S/ha with three weeding(S_2W_3) followed by S_2W_2. The lowest number of seed (870.7) was found from no weeded plants with control sulphur treatment.

4.6.5 . 1000-seed weight

The weight of seed is related with the magnitude of seed development because it is an important yield determinant factor and plays a decisive role in expression of yield potential of a variety (Sana *et al.*, 2003). It is evident from the study that 1000-seed weight of rapeseed greatly affected the yield.

Table 19. Yield attributes of rapeseed as affected by the interaction of sulphur rate and number of weeding

Treatmets	No. of siliqua plant-1	No. of seeds siliqua-1	No. of seeds plant-1	1000-seed weight (g)
S0W0	52.23 d	16.67 l	870.7 n	2.747 c
S0W1	54.05 cd	16.93 l	915.2 m	2.743 c
S0W2	54.61 c	18.35 j	1002. k	2.783 c
S0W3	53.65 d	17.85 k	957.5 l	2.783 c
S1W0	54.93 c	17.45 k	958.4 l	2.753 c
S1W1	60.84 b	19.01 hi	1156. i	2.847 a-c
S1W2	70.92 a	19.56 fg	1387. g	2.900 a-c
S1W3	70.75 a	20.50 bc	1457. c	3.027 ab
S2W0	60.49 b	19.35 gh	1364. h	2.803 bc
S2W1	70.89 a	19.80 e-g	1404. f	2.927 a-c
S2W2	72.06 a	20.75 ab	1497. b	3.060 a
S2W3	71.61 a	21.06 a	1508. a	3.067 a
S3W0	61.86 b	18.56 ij	1148. j	2.820 bc
S3W1	71.89 a	20.03 d-f	1440. d	2.960 a-c
S3W2	70.79 a	20.53 bc	1439. d	3.023 ab
S3W3	70.83 a	20.77 ab	1429. e	3.027 ab
SX value	**0.564**	**0.142**	**2.330**	**0.065**
CV (%)	**2.57**	**0.55**	**2.26**	**0.77**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control　　W_0 =Control
S_1 = 15 kg Sulphur per ha　　W_1 =One hand weeding at 15 DAS
S_2 = 30 kg Sulphur per ha　　W_2 =Two hand weeding at 15,30 DAS
S_3 = 45 kg Sulphur per ha　　W_3 =Three hand weeding at 15, 30 and 45 DAS

Effect of sulphur

Thousand seed weight of rapeseed was significantly influenced by sulphur rate (Table 17). The highest 1000-seed weight of 2.98 g was recorded from S_2 (30kg S/ha)but it was statistically identical with the seed weight obtained from S_3 (45kg S/ha). The lowest 1000-seed weight (2.76 g) was found from the S_0(control). 1000-seed weight was higher because inter-plant competition for nutrients was less and the plants got more nutrients for better seed development which finally resulted with heavier seeds.

Effect of weeding

From Table 18, it was seen that weeding had significant effect on 1000-seed weight. Three weeding at 15DAS, 30 DAS and 60 DAS produced the highest 1000-seed weight of 2.97 g which was significantly identical to 2.94 g produced by two weeding applied at 15 DAS and 30 DAS. The lowest 1000-seed weight (2.80 g) was produced by plants without weeding (control). Weeding is an important factor, which facilitates the proper use of plant nutrition, air and space by the plant to promote the seed yield. In this study three weeding produced the highest 1000-seed weight which was significantly superior to that produced by no weeding.

Interaction effect of sulphur and weeding

In this study, interaction effect of sulphur and weeding was found significant in relation to 1000-seed weight of rapeseed (Table 19). The highest weight of 1000 seed (3.067 g) was found from the combination of three weeding at 15 DAS, 30 DAS and 60 DAS with 30 kg S/ha (S_2 W_3), which was statistically identical with S_2W_2 (3.060 g). The lightest seed was found from the treatment combination of no weeding and no sulphur (S_0W_0). However, the combination of the all the weeding treatment with no sulphur treatment and all the sulphur treatment with no weeding treatment were found statistically identical.

4.7 Seed yield per plant

Effect of sulphur

In the present study, significant variation was found in seed yield per plant at different sulphur rate (Table 20). Among the treatments S_2 (30 kg S/ha) produced the highest seed yield per plant (4.312 g) which was followed by S_3 (45 kg S/ha) where as S_0 produced the lowest seed yield per plant (2.58 g). Seed yield plant^{-1} from S_2 (30 kg S/ha) and S_3 (45 kg S/ha) was 41.27% and 35.99% higher than S_0 (control). The treatment S_3 provided the maximum sulphur which produced leaves with more chlorophyll content, rate of photosynthesis and the partitioning of photosynthate was thus effectively translocated to the reproductive part. The reduction in seed yield per plant might be due to cumulative effect of less number of siliqua, smaller seed size, less number of seed per siliqua at S_0 (control).

Effect of weeding

Seed yield per plant is a complex character which depends on the different yield contributing characters such as number of branches, siliqua per plant, seed per siliqua, 1000-seed weight etc. In this study seed yield per plant was significantly influenced by different weeding treatments (Table 18) which ultimately affected the characters as mentioned above. The treatment W_3 (three weeding- at 15DAS,30 DAS and 60 DAS) produced the highest seed yield per plant (4.007 g) which was statistically identical to W_2 (two weeding at 15 DAS and 30 DAS) (3.934 g) and the least seed yield was found at W_0 (no weeding) (3.050 g). The increased seed yield plant^{-1} with three weeding (W_3) and two weeding (W_2) was 23.89 % and 22.48% higher than without weeding (W_0). The treatment W_3 produced the highest number of branches, siliqua per plant, seed per siliqua, 1000-seed weight which ultimately increased the yield per plant. So it might be concluded that the yield was increased as the number of weeding increased.

Interaction effect of sulphur and weeding

Significant interaction between sulphur and weeding was found for the production of seed yield per plant in rapeseed (Table 22). Among the treatments S_2W_3 produced the highest seed yield per plant (4.623 g) which was statistically identical with 30 and 45 kg S/ha combined with two and three weeding. S_0 W_0 produced the lower seed yield per plant (2.390 g) which was statistically identical with no sulphur application combined with all the weeding treatment.

Table 20. Yields and Harvest index of rapeseed as affected by sulphur dose

Treatments	**Seed yield per plant(g)**	**Seed yield per ha (t)**	**Stover yield (t)**	**Biological yield (tons)**	**Harvest index (%)**
S0	2.588 d	1.241 d	3.545 c	4.787 c	25.94 d
S1	3.591 c	1.724 c	3.994 b	5.717 b	29.88 c
S2	4.312 a	2.070 a	4.508 a	6.383 a	32.43 a
S3	4.043 b	1.941 b	4.270 ab	6.212 a	31.14 b
SX value	**0.039**	**0.026**	**0.084**	**0.041**	**0.086**
CV(%)	**1.74**	**1.81**	**7.31**	**1.22**	**1.05**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control
S_1 = 15 kg Sulphur per ha
S_2 = 30 kg Sulphur per ha
S_3 = 45 kg Sulphur per ha

Table 21. Yield and Harvest index of rapeseed as affected by number of weeding

Treatments	Seeds yield per plant (g)	Seeds yield per ha (t)	Stover yield(t)	biological yield(t)	Harvest index
W0	3.050 c	1.463 c	3.848 b	5.117 c	28.35 c
W1	3.543 b	1.701 b	3.973 ab	5.673 b	29.68 b
W2	3.934 a	1.889 a	4.227 ab	6.118 a	30.62 a
W3	4.007 a	1.923 a	4.269 a	6.192 a	30.73 a
SX value	**0.040**	**0.028**	**0.085**	**0.041**	**0.109**
CV (%)	**1.92**	**1.96**	**7.39**	**1.24**	**1.66**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 levels of significance.

W_0 = Control
W_1 = One hand weeding at 15 DAS
W_2 = Two hand weeding at15DAS and 30 DAS
W_3= Three hand weeding at 15 DAS, 30 DAS and 45 DAS

Table 22. Yields and Harvest index of Rapeseed as affected by the interaction of sulphur rate and number of weeding

Treatments	Seed yield plant-1 (g)	Seed yield t ha^{-1}	Stover yield t ha^{-1}	Biological yields t ha^{-1}	Harvest index (%)
S0W0	2.390 e	1.147 e	3.397 d	4.547 i	25.26 f
S0W1	2.510 e	1.203 e	3.380 d	4.583 i	26.29 ef
S0W2	2.787 e	1.337 de	3.590 b-d	5.130 gh	26.09 ef
S0W3	2.667 e	1.277 e	3.613 b-d	4.890 hi	26.14 ef
S1W0	2.640 e	1.270 e	3.470 cd	4.737 i	26.74 e
S1W1	3.290 d	1.580 d	3.887 a-d	5.467 fg	28.89 d
S1W2	4.020 bc	1.930 bc	4.150 a-d	6.080 de	31.75 bc
S1W3	4.113 bc	1.927 bc	4.470 a	6.387 bc	31.14 bc
S2W0	3.937 c	1.887 c	3.637 b-d	5.747 ef	31.56 bc
S2W1	4.107 bc	1.973 a-c	4.277 a-c	6.247 cd	31.56 c
S2W2	4.580 a	2.200 ab	4.523 a	6.723 ab	32.70 ab
S2W3	4.623 a	2.220 a	4.593 a	6.813 a	32.86 a
S3W0	3.233 d	1.550 d	3.687 b-d	5.437 fg	28.54 d
S3W1	4.163 bc	2.047 a-c	4.347 ab	6.393 b-d	31.69 bc
S3W2	4.350 ab	2.090 a-c	4.447 ab	6.540 a-c	31.65 bc
S3W3	4.323 a-c	2.077 a-c	4.400 ab	6.477 a-d	31.66 bc
SX value	**0.115**	**0.081**	**0.240**	**0.117**	**0.308**
CV (%)	**1.92**	**1.96**	**7.39**	**1.24**	**1.66**

NB: Figures in a column followed by same letter do not differ significantly at 0.05 level of significance.

S_0 = Control — W_0 =Control
S_1 = 15 kg Sulphur per ha — W_1 =One hand weeding at 15 DAS
S_2 = 30 kg Sulphur per ha — W_2 =Two hand weeding at 15,30 DAS
S_3 = 45 kg Sulphur per ha — W_3 =Three hand weeding at 15, 30 and 45 DAS

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

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 per hectare. Table 4.20 showed the significant variation in seed yield per hectare at different sulphur application ranging from 1.241 to 2.072 tons. The treatment S_2 produced the significantly highest seed yield (2.070 t ha^{-1}) which was followed by S_3 (1.941 t ha^{-1}). The maximum seed yield ha^{-1} with 30 kg S/ha was 40.05% and 26.72% higher than the yield obtained from control and application of 15 kg S/ha. This indicated that the application of sulphur must be optimum to achieve the highest seed yield. The treatment S_0 produced the lowest yield (1.241 t 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.

Effect of weeding

Weeding significantly increased the seed yield per hectare in rapeseed. Maximum seed yield per hectare (1.923 tons) was found from three weeding (at 15DAS, 30 DAS and 60 DAS) which was statistically identical with W_2(two hand weeding at 15 DAS and 30 DAS) which were 33.39% and 21.55% higher than the yield obtained from the control treatment (W_0) and one weeding (W_1). The lowest seed yield ha^{-1} was found from control (1.463 t ha^{-1}).

Interaction effect of sulphur application and weeding

Interaction between sulphur application and weeding played an important role for promoting the yield. Table 22 showed significant variation in interaction effect between sulphur application and weeding. Among the treatments S_2W_3 produced the highest seed yield (2.220 t ha^{-1}) which was 41.18% higher than the lowest yield. It was statistically identical with S_2W_2 (2.20 t ha^{-1}), S_3W_2 (2.090 t ha^{-1})and S_3W_3 (2.077 t ha^{-1}). The lowest seed yield was obtained from S_0W_0 (1.149 t ha^{-1}).

4.9. Stover yield

Effect of sulphur application

Stover yield of rapeseed was greatly affected by sulphur as it was determined by plant dry matter wieght. Table 20 showed significant variation in stover yield among the sulphur application. Among sulphur application S_2 produced the significantly highest stover yield (4.508 t ha^{-1}) which was statistically identical with S_3.It was 21.57% and 11.41% higher than the stover yield obtained from control (S_o) and 15 kg S/ha (S_1).Lowest stover yield was found from S_0 (control).

Effect of weeding

The increased number of weeding increased the plant height, number of branches, number of leaves, length of the inflorescence which ultimately increased the stover yield. In this study, no significant variation was found in stover yield at different weeding treatment (Table 21). The treatment W_3 produced the highest stover yield (4.269 t ha^{1}) which was statistically defferent from W_2 and W_1. In the previous discussion it was shown that the W_3 treatment produced the tallest plant height, number of branches per plant and number of siliqua per plant, which cumulated to increase the stover yield. The treatment W_0 (no weeding) produced the lowest stover yield (3.848 t ha^{-1}).

Interaction effect of sulphur application and weeding

The sulphur application along with different weeding showed no significant variation in producing stover yield. Table 22 showed that the treatment S_2 W_3 produced the highest stover yield (4.593 ha^{-1}) which was statistically identical with all the combination except sulphur at control treatment where as the treatment S_0 W_0 produced the lowest stover yield (3.397 ha^{-1}).

4.10. Biological Yield

Biological yield is the summation of seed yield and stover yield which was greatly influenced by different sulphur application and weeding.

Effect of sulphur application

The rate of sulphur is an important factor for biological yield per unit area because sulphur enhanced the reproductive growth and the proportion of the reproductive tissues (inflorescences and pods) in total dry matter. In this experiment, Table 20 showed that the sulphur application had significant effect on biological yield. The highest biomass (6.383 t ha^{-1}) was produced at S_2 (30 kg S/ha) which was significantly identical from biomass produced at S_3 (45 kg S/ha). The lowest was found at S_0 (control).

Effect of weeding

Different weeding treatment produced significantly variation in biological yield of rapeseed. Among the treatment W_3 produced the highest biological yield (6.192

ha^{-1}) which was statistically identical with W_2. The control treatment produced the lowest biological yield (5.117 t ha^{-1}) . Table 21 showed that W_3 increased not only seed yield but also stover yield. Reproductive development as well as vegetative growth promoted the biological yield. Stover yield was equally important for seed yield as well as biological yield. Biological yield increased with the increase of weeding number.

Interaction effect of sulphur application and weeding

Table 22 showed that the combined effect of sulphur application and weeding influenced the biological yield in the present study. The treatment S_2W_3 produced the highest biological yield and it was statistically identical with S_2W_3 and S_3W_2. The lowest biomass was found from the treatment S_0W_0 which was statistically identical with S_0W_1 but significantly different from the other.

4.11. Harvest index

Harvest index is the ratio of economic yield and biological yield and it was also influenced by different sulphur application and weeding.

Effect of sulphur

Different sulphur application affected the reproduction and growth of rapeseed. In this study sulphur application had significant effect on harvest index (Table 20). The treatment S_2 produced the highest harvest index (32.43%) which was followed by S_3 (31.14%). Lowest harvest index was found with S_0 (control).

Effect of weeding

It was observed from Table 21 that different weeding treatment had significant effect on harvest index. W_3 gave the highest harvest index (30.73%) and it was significantly different from the treatments W_2. The lowest value of harvest index (28.35%) was obtained from the treatment W_0 (control). Three weeding at 15 DAS, 30 DAS and 45 DAS produced higher seed yield which increased the harvest index. At W_0 treatment the plant was suffered from severe competition with resources and thus poor seed was reproduced.

Interaction effect of sulphur application and weeding

Interaction between sulphur application and weeding may be important determining factor for harvest index. Table 22 showed the significant interaction between sulphur and weeding for harvest index where the treatment S_2 W_3 produced the highest harvest index (32.86%) which was followed by S_2 W_2 (32.70%). The treatment S_0 W_0 produced the lowest harvest index (25.26%).

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The study was carried out to find out the optimum sulphur dose and appropriate number of weeding to get optimum yield of rapeseed. The results are summarized below.

The rapid increase in plant height was observed from 30 DAS to 75 DAS. Increased rate of sulphur (30kg/ha) ultimately produced the tallest plant than control and application of sulphur @ 15 kg/ha as the plants got sufficient amount of nutrients for proper growth and development. Significant variation was found in plant height among the weed management treatment. The maximum plant height was found from three times weeding. The interaction effect of sulphur and weeding showed significant plant height of rapeseed. Maximum plant height was found from the treatment combination of three weeding and 30 kg sulphur per hectare in all the stage of life cycle.

Total dry matter varied at all the growth stages with different sulphur rate. The application of sulphur @ 30 kg/ha produced the highest dry matter at all the development stages. It also played an important role in dry matter partitioning. Significant variation was found in total dry matter plant^{-1} among the different sulphur treatment except 15 DAS. Dry matter partitioning was also greatly influenced by sulphhur and similarly above treatment gave the best result. In case of weeding treatment , three weeding at 15DAS, 30DAS and 45DAS gave the best result as the weeding provided favourable condition for proper growth and development

In case of interaction effect, the treatment combination of three weeding and application of sulphur @ 30kg/ha produced the highest dry matter after 45 DAS which seemed to be most effective treatment for dry matter production. This treatment also influenced the dry matter of the partitioning components.

Leaf area per plant was increased with the increase of sulphur rate upto 30 kg/ha. The maximum leaf area was found with the application of sulphur @ 30 kg /ha while control treatment gave the minimum leaf area. The maximum leaf area was also found with three weeding at 15DAS, 30DAS and 45DAS while the minimum leaf area was found from control treatment. Maximum leaf area was found from the treatment combination of three weeding and 30 kg sulphur per hectare .

The highest number of branches plant^{-1} (6.73333) was found with the application of sulphur @ 30 kg/ha and the lowest (5.133) from the control treatment. The maximum number of branches was found from a plant when three weeding was applied at 15 DAS, 30 DAS and 45 DAS. The lowest numbers of branches were found from control plots. On the other hand, the treatment combination of three weeding and application of sulphur @ 30kg/ha produced the maximum branches plant^{-1} (7.33).

The number of siliqua plant^{-1} gradually increased with the increase in sulphur rate upto 30 kg/ha. The application of sulphur @ 30 kg/ha produced more number of siliqua plant^{-1} than other treatment. Among the weeding treatment, two weeding at 15 DAS and 30 DAS produced the highest number of siliqua plant^{-1} which was statistically identical from three weeding. All the combination except control gave statistically identical results.

Number of seeds siliqua^{-1} also significantly was affected by different sulphur rate. The highest number of seeds siliqua^{-1} (20.25) was found with the application of sulphur @ 30 kg/ha and the lowest (17.45) from the control treatment. Number of seeds siliqua^{-1} increased with the increase number of weeding. Treatment combination of three weeding and application of sulphur @ 30kg/ha was found to be superior for producing the seeds siliqua^{-1} which was statistically identical with the combination of three weeding and application of sulphur @ 45 kg/ha.

The highest number of seeds plant^{-1} was found with the application of sulphur @ 30 kg/ha and the lowest from the control treatment. The maximum number of seeds plant^{-1} was found from a plant when three weeding was applied at 15 DAS, 30 DAS and 45 DAS. The lowest numbers of seeds plant^{-1} were found from control plots. On the other hand, the treatment combination of three weeding and application of sulphur @ 30kg/ha produced the maximum seeds plant^{-1}.

1000 seed weight was increased with the increase of sulphur rate up to 45 kg/ha. Application of sulphur @ 45 kg/ha produced the highest 1000 seed weight which was statistically identical with the application of sulphur @ 30 kg/ha and the lowest from control. Three weeding at 15 DAS,30 DAS and 45 DAS produced the highest 1000-seed weight followed by two weeding at 15 DAS and 30 DAS. All the combination except combination with control treatment of both or any one gave the statistically identical results.

Seed yield plant^{-1} is a complex character which depended on the different yield contributing characters. The highest number of seed yield plant^{-1} (4.312 g) was found with the application of sulphur @ 30 kg/ha (S_2) which was followed by S_3 (45 kg S/ha) and the lowest (2.588 g) from the control treatment (S_0). Seed yield plant^{-1} from S_2 was 39.99% and 16.73% higher than S_0 and S_1 . This yield also significantly influenced by the number of weeding and three weeding at 15 DAS, 30 DAS and 45 DAS produced the highest seed yield plant^{-1} which was statistically identical with two weeding at 15 DAS and 30 DAS and the least yield was found from control (W_0). The increased seed yield plant^{-1} with three weeding (W_3) was 11.58 % and 23.88% higher than one weeding (W_1) and without weeding (W_0). Three weeding (W_3) combined with the application of sulphur @ 30 kg/ha (S_2) produced the highest seed yield plant^{-1} which was statistically identical with S_2W_2, S_3W_2 and S_3W_3.

The maximum seed yield ha^{-1} found with the application of sulphur @ 30 kg/ha (S_2) was 40.04% and 16.71% higher than the yield obtained from S_0 and S_1. Maximum seed yield ha-1 was found from three weeding - at 15 DAS, 30 DAS and 45 DAS (W_3) which was statistically identical with two weeding at 15 DAS and 30 DAS (W_2). Seed yield ha-1 obtained from W_3 were 23.92% and 11.54% higher than the yield obtained from the control treatment (W_0) and one weeding (W_1). In case of interaction effect, among the treatment three weeding (W_3) combined with the application of sulphur @ 30 kg/ha (S_2) produced the highest seed yield (2.220 t ha^{-1}) .

Among sulphur treatment S_2 (30 kg S/ha) produced the highest stover yield. Incase of weeding all treatments except control produced the statistically identical stover yield. The highest biological yield was produced from the application of sulphur @ 30 kg/ha (S_2) and control (S_0) produced the lowest biological yield ha^{-1} in this study. Among different weeding treatment three weeding - at 15 DAS, 30 DAS and 45 DAS (W_3) produced the highest biological yield ha^{-1} which was statistically identical with two weeding at 15 DAS and 30 DAS (W_2). The interaction effect of three weeding (W_3) combined with the application of sulphur @ 30 kg/ha (S_2) produced the highest biological yield which was statistically identical with S_2W_2, S_3W_2 and S_3W_3.

The treatment S_2 (30 kg S/ha) produced the highest harvest index and three weeding at 15 DAS, 30 DAS and 45 DAS (W_3) produced the highest harvest index which was statistically identical with two weeding at 15 DAS and 30 DAS (W_2) and the combination of three weeding (W_3) combined with the application of sulphur @ 30 kg/ha (S_2) was found to be best for harvest index for the rapeseed in this study.

From the present study it may be concluded that sulphur rate and weeding influenced the growth, yield and yield components of rapeseed. Among the different weeding treatment three weeding - at 15 DAS, 30 DAS and 45 DAS (W_3) gave the best result which was statistically identical with two weeding at 15 DAS and 30 DAS (W_2).

Among sulphur treatment the S_2 (30 kg S/ha) provided the best result among the treatments. The interaction effect of three weeding (W_3) combined with the application of sulphur @ 30 kg/ha (S_2) were found most effective.

However, further field trial may be taken to confirm and justify these results.

REFERENCES

REFERENCES

Abdin, M. Z., Khan, N., Khan, I., Israr, M. and Jamal, A. (2003). Nitrogen and sulphur interaction in relation to yield and quality attributes of rapeseed-mustard. *Indian J. Fert.* **5**(3/4): 35-41 .

Ahmad, A., Khan, I. and Abdin, M. Z. (2000). Effect of S fertilization on oil accumulation, acetyl-CoA concentration and acetyl-CoA carboxylase activity in the developing seeds of rapeseed (*Brassica campestris* L.). *Aust. J. Agric. Res*. **51**: 1023–1029.

Ahmad, S., Fazili, I. S., Jamal, A., Iqbal, M., and Abdin, M. Z. (2007). Interactive effect of sulphur and nitrogen on nitrate reductase and ATP-sulphurylase activities in relation to seed yield from *Psoralea corylifolia* L. *J. Plant Biol*. **50**: 351–357.

Alam, M. M. (2004). Effect of variety and row spacing on the yield and yield contributing characters of rapeseed and mustard. M. S. Thesis. Department of Agronomy, Bangladesh Agricultural University., Mymensingh. p.3.

BARI (Bangladesh Agricultural Research Institute). (2002). Status of Oilcrop Production in Bangladesh. Oilseed Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2004). Statistical Yearbook of Bangladesh. Statistics Division, Ministry of Planning, Government of the People Republic of Bangladesh.

BCA (Bangladesh Country Almanac). (2009). Agricultural Statistics Database. *In* BCA v.2.0 (CD ROM Version). CIMMYT Bangladesh.

Bhadoria, R.B.S. and Chauhan, D.V.S. (1995). Effect of fertilizer and weed control in Indian mustard *(Brassica juncea*). *Weed Abst*. **44**(8): 451.

Bhargava, S. C. (1991). Physiology. *In*: Oilseed Brassica in Indian Agriculture. *Eds*. U. L.Chopra and Shyan Prakas. Har-Anand Publications and Vikas Pulish Pvt. Ltd. pp.161-197.

Bharose, R., Chandra, S., Thomas, T. and Dhan, D. (2011). Effect of different levels of phosphorus and sulphur on yield and availability of N P K, protein and oil content in Toria (*Brassica Sp.*) Var. P.T.–303, *Arpn J. Of Agric.. And Biological Sci* . **6**(2):

Bharti, V. and Prasad, U. K. (2001). Effect of irrigation and sulphur levels on growth and yield of rai (*Brassica juncea* L.). *J. of Applied Biology*. **11**(1/2): 31-34.

Biswas, D. R., Ali, S. A. and Khera, M. S. (1995). Response of Ghobi sarson (*Brassica napus* L. ASN-706) to nitrogen and sulphur. *J. Indian Soc. Soil Sci*. **43**: 220-225

Chaubey, A. K., Kaushik, M. K. and Singh, S. B. (2001). Phosphorus and sulphur fertilization in relation to yield attributes and seed yield of Indian mustard (*Brassica juncea*). *J. of Applied Biology* **11**(1/2): 53-56.

Chauhan D.R., Paroda, S. and Ram, M. (1996). Response of Indian mustard to bio-fertilizers. sulphur and nitrogen fertilization. *Indian J. Agron*. **41**(4): 600-603.

Chauhan, Y. S. and Bhargava, S. C. (1984). Physiological analysis of growth and yield variation of rapeseed and mustard. *J. Agric. Sci., Cambridge*. **103**: 249-152.

Dabhi, M. K., Gupta, D. G. and Patel, J. J. (2010). Green-Farming :Response of sulphur application on growth, yield attributes and yield of mustard under middle Gujarat conditions. *Arpn J. Of Agricultural And Biological Sci* . **5**(3): 272-273.

Davaria, R. L., Khanpara, V. D., Kaneria, B. B., Mathukia, R. K.and Asodaria, K. B. (2001). Effect of phosphorus and sulphur on growth, yield, quality and nutrient content of mustard (*Brassica juncea*). *Gujarat Agril. Uni. Research J*. **26**(2): 77-79.

Dixit, A. and Gautam, K. C. (1996). Nutrient concentration and its depletion in Indian mustard (*Brassica juncea*) as influenced by fertilizer, irrigation and weed control. *Indian J. Agron.* **41**(1): 167-169.

Donald, C. M. (1963). Competition among crops and pasture plants. *Adv. Agron*. **15**: 1-118.

Downey, R. K. and Rimmer, S. R. (1990). Agronomic improvement in oilseed Brassica. *Indian J. Agron*. **35**: 1-66.

Duhan, B. S., Grewal, K. S., Singh, B. and Satyavan, D. (2006). Effect of sulphur on yield and nutrients uptake by two cultivars of raya. *Haryana J. of Agron*. **22**(2): 161-163.

FAO. (1998). Production Yearbook. Food and Agricultural Organization of the United States, Rome 00100, Italy.

FAO. (2001). Production Yearbook. Food and Agricultural Organization of the United States, Rome 00100, Italy.

Fazili, I. S., Ahmad, S., Jamal, A. and Abdin, M. Z. (2005). Changes in oil and fatty acid composition of developing seeds of taramira (*Eruca sativa* Mill.) as influenced by sulphur and nitrogen nutrition. *Indian J. Plant Physiol.* **10**: 354–361

Franzen, D. W. and Grant C. A. (2008). Sulphur Response Based on Crop, Source, and Landscape Position. In: Jez, J. (Ed.), Sulphur: A Missing Link between Soils, Crops, and Nutrition. American Society of Agronomy, Madison, WI, pp. 105-116.

Gaffer, M. A. (1984). A comprehensive study on weeds, their infestations and agronomic means of control in the arable land of Bangladesh. Ann. Rept. No. 1. Dept. of Agron., BAU, Mymensingh, pp: 61-63.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical procedure for Agricultural Researc*h. 2nd Edition. A Willey-Interscience Publication. pp. 130-240.

Hegde, D. M. and Murthy, I. Y .L. (2005). Management of Secondary Nutrients. Achievements and Challenges. *Indian J. Fert.* **1**: 93-100

Jat, B. L., Jangir, R. P. and Khangarot, S. S. (2003). Responses of mustard varieties to different levels of sulphur in loamy sand soil. *J. Farm. Syst. Res. Dev.* **8**(1): 108-109.

Jat, J. R. and Mehra, R. K. (2007). Effect of sulphur and zinc on yield, macronutrient content and uptake by mustard. *J. Indian Soc. Soil Sci.* **55** (2): 190-195.

Kachroo, D. and Kumar, A. (1997). Nitrogen and sulphur fertilization in relation to yield attributes and yield of Indian mustard (*Brassica juncea*). *Indian J. Agron.* **37**(3): 549-551.

Kaul, A. K. and Das, M. L. (1986). Oilseed in Bangladesh. Bangladesh-Canada Agriculture Sector Team, Ministry of Agriculture, Government of the People"s Republic of Bangladesh, Dhaka.

Khalid, R., Khan, K. S., Yousaf, M., Shabbir, G. and Subhani, A. (2009). Effect of sulphur fertilization on rapeseed and plant available sulphur in soils of Pothwar, Pakistan. *Sarhad J. Agric.* **25**(1): 65-71.

Khanpara, V. D., Porwal, B. L., Sahu, M. P. and Patel, J. C. (1993). Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea*). *Indian J. Agron.* **38**(2): 266-269.

Kumar, H. and Yadav, D. S. (2007). Effect of phosphorus and sulphur levels on growth, yield and quality of Indian mustard (*Brassica juncea*) cultivars. *Indian J. Agron.* **52**(3): 154-157.

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

Kumar, S., Verma, S. K., Singh, T. K. and Singh, S. (2001). Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (Brassica juncea) under rainfed condition. *Indian J. of Agril. Scis.* **81**(2): 145-149.

Malavia, D. D., Petal, J. C. and Vyas, M. M. (1988). Studies on irrigation, nitrogen and phosphorus levels on growth and yield of mustard. *Indian J. Agron*. **33**: 245-248.

Malhi, S. S. and Gill, K. S. (2002). Effectiveness of sulphate-S fertilization at different growth stages for yield, seed quality and S uptake of canola. *Canad. J. Plant Sci.* **82**: 665-674.

Mandal, K. G. and Sinha, A. C. (2004). Nutrient management effects on light interception, photosynthesis, growth, dry-matter production and yield of Indian mustard (*Brassica juncea*). *J. Agron. Crop Sci.,* **190** (2): 119–129.

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

Mehdi, S. S. and Singh, O. P. (2007). Effect of various levels of sulphur fertilization on growth and yield of Indian mustard (*Brassica juncea* L.) under subtropical conditions. Calcutta, India: MKK Publication. **25**(2): 241-243.

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

Munshi, S. K., Vats, S., Dhillon, K. S.and Sukhija, P. S. (1990). Lipid biosynthesis in seeds of mustard (*Brassica juncea* L.) influenced by zinc and sulphur deficiency. *J Physiol*. **80**: 102–108.

Nepalia, V. (2005). Influence of weed control and sulphur on growth, yield and economics of mustard production. *J*. *Agron*. **6**(1): 35-38.

NNC (National Nutritional Council). (1984). Nutritional policy and program for Bangladesh. National Nutritional Council, Dhaka, Bangladesh.

Patel, J. J., Gupta, D. G. and Dabhi, M. K. (2010). Response of sulphur application on growth, yield attributes and yield of mustard under middle Gujrat conditions. *Indian J. Plant Physiol.* **13**(3) : 272-273.

Patel, J. R. and Shelke, V. B. (1998). Effect of farmyard manure, phosphorus and sulphur on growth, yield and quality of Indian mustard (*B. juncea). J.Agron.* **43**(4): 713-717.

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

Piri, I. and Sharma, S. N. (2007). Effect of sulphur on yield attributes and yield of Indian mustard (*Brassica juncea*) as influenced by irrigation. *Indian J. of Agril. Sciences*. **77**(3): 188-190

Piri, I., Nik, M. M., Tavassoli, A. and Rastegaripour, F. (2011). Effect of irrigation intervals and sulphur fertilizer on growth analyses and yield of *Brassica juncea*. *African J. Microb. Res* . **5**(22): 3640-3646.

Prakash, O. and Singh, B. P. (2002). Effect of sulphur fertilization on growth, yield and quality of Indian mustard (*Brassica juncea* L.) genotypes. *J Applied Bio*.**12**(2): 275-279.

Prasad, J. (1995). Studies on sulphur use efficiency of mustard (*B. juncea*) as influenced by rate of gypsum application and levels of irrigation. M.Sc. (Ag) Thesis, RAU, Bikaner (Raj), pp. 23-37.

Prasad, K., Chaudhary, H. P. and Uttam, S. K. (2003). Effect of nitrogen, phosphorus, sulphur and zinc on growth, yield attributes and yield of mustard under rainfed condition. *Indian J. of Plant Physiol.* **18**(3/4): 124-129.

Rana, K. S., Rana, D. S. and Kumar, P. (2001). Growth and yield of taramiric (*Ericca sativa*) as affected by nitrogen and sulphur under dryland condition. *Indian J. Agron*. **46(**1): 168-170.

Rashid, R., Karim, M. F. and Hasanuzzaman, M. (2007). Response of Rapeseed (*Brassica campestris* L.) to different nitrogen doses and number of weeding. *Middle-East J. Sci. Res.* **2** (3-4): 146-150.

Raut, R. F., Hamid, A., Hadole, S. S., Jeughale, G. S. and Sajid, M. (1999). Dry matter and grain yield of mustard as influenced by irrigation and sulphur levels. *Indian J. of Plant Physiol*. **13**(2): 118-122.

Sah, D., Bohra, J. S. and Srivastava, R. K. (2005). Nitrogen, phosphorus and sulphur fertilization in relation to yield attributes and yields of Indian mustard (*Brassica juncea* L. Czern & Coss). Calcutta, India: MKK Publication. **23**(2): 338-341.

Saha, A. and Mandal, B. K. (2000). Growth and yield of yellow sarson and mustard in relation to sulphur nitrogen in lowland entisol under rainfed condition. *J. Oilseeds Res*. **17**(2): 307-314.

Sana, M., Ali, A., Malik, M. A., Saleem, M. F. and Rafiq, M. (2003). Comparative yield potential and oil contents of different canola cultivars (*Brassica napus* L.). *Pak. J. Agron*. **2**(1): 1-7.

Shaheenuzzamn, M., Ahmed, I. M., Karim, M. M., Haider, S. M. S., Raquibullah, S.M. and Ahmed, M. H. (2010). Herbicidal control of weed in mustard field. *Int. J. Expt. Agric.* **1**(1): 15-19.

Sharma, J. P. (1994). Response of Indian mustard to different irrigation schedules and nitrogen and sulphur levels. *Indian J. Agron*. **39**: 421-425.

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

Sharma, Y. K. (2008). Effect of phosphorus and sulphur on yield and uptake of nutrients by mustard. *Ann. Pl. Soil Res.* **10(**2) : 195-196.

Singh, B., Singh,J., Kumar, A., Yadav, Y.P. and Singh, S. (1999). Response of *Brassica* to sulphur for yield. *Ind. J. Agric. Sci*. **69**: 427-431.

Singh, M., Singh, D. B., Ganandra, G., Singh, M. and Giri, G. (1997). *J. Agric. Res*. **18**(2): 135-142.

Singh, P., Kant, R. H., Singh, P., Bahar, F. A., Singh, K. N., Panotra, N. and Sawhney, S. K. (2010). Influence of sulphur and potassium nutrition on yield and quality of brown sarson (*Brassica compestris* L.) in temperate Kashmir research. *J.Agric. Sci*. **1**(2): 85-88.

Singh, S. S. (1992). Effect of fertilizer application and weed control on the yield of mustard (*Brassica juncea*). *Indian J. Agron***. 37**(1): 196-198.

Singh, V. Singh, U. P., Lodhi, M. D., Pandey, B. K. and Verma, N. K. (2007). Effect of phosphorus and gypsum levels on growth and yield of mustard (*Brassica juncea* coss) variety 'Varuna'. *Indian J.Agron*. **52**(3): 124-127.

Singh, V., Lodhi, M. and Verma, N. K. (2008). Effect Of phosphorus and sulphur levels on growth and yield of mustard variety „Varuna". *Agric. Sci. Digest.*. **28**(1): 59-60.

Singh, V., Lodhi, M. and Verma, N .K. (2008). Effect of phosphorus and sulphur levels on growth and yield of mustard (Brassica juncea Coss) variety 'Varuna'. *Journal of the Indian J. Soc. oSoil Sci*. **56**(1): 59-60.

Stryer, L. (1980). *Fatty acid metabolism in Biochemistry* (2nd ed.). Stamford Univ. Freeman Co., New York, San Francisco. p.385.

Subhani, A., Shabir, G., Fazil, M., Mahmood, A. Khalid, R. and Cheema, N. M. (2003).

Role of sulphur in enhancing the oil contents and yield of rapeseed under medium rainfed conditions. *Pak. J. Soil Sci*. **22**: 50-53.

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

Tekale, K. U., Khanpara, V. D., Deshmukh, M. S.and Bonde, A. M. (2005). Effect of weed management practices on growth and yield contributing parameters of Indian mustard and their correlation with yield. *J. Soils Crops*. **15**(1): 183-186.

Tiwari, K. N. and Gupta, B. R. (2006). Sulphur for Sustainable high yield Agriculture in Uttar Pradesh. *Ind. J. Fert.* **1** (11): 37-52.

Tomar, R. K. S., Chourasia, S. C. Raghu, J. S. and Singh, V. B. (1996). Growth, yield and net returns of mustard under different levels of Nitrogen and Sulphur application on clay loam soils. *J. Oil Seed Res*. **13**(1): 13-17.

Tomar, T. S., Singh, S., Kumar, S. and Tomar, S. (1997). Response of Indian mustard to nitrogen, phosphorus and sulphur fertilization. *Indian J. Agron.* **42**(1): 148-151.

Varma, S. C., Srivastava, R. K., Singh, R., Singh, S. K. and Bisen, P. K. (2002). Effect of varying levels of sulphur and potassium on yield and oil content of Indian mustard. *Indian J. of Plant Physiol***.** **16**(3): 650-652.

Verma, C. K., Prasad, K. And Yadav, D. D. (2012). Studies on response of sulphur, zinc and boron levels on growth and yield of mustard. *Indian J. of Plant Physiol*. **12** (1): 19-21

Yadav, K. S., Rajput, R. L. and Agarkar M. S. (1999). Effect of sowing dates and irrigation schedules on yield and water use efficiency of Indian mustard. *Indian J. Agron*. **44**: 148-150.

Zhao, F., Bilsborrow, P. E., Evans, E. J. and Syers, J. K. (1993). Sulphur turnover in the developing pods of single and double row varieties of oilseed rape. *J. Sci. Food Agri.* **4**:111-119.