EFFECT OF PHOSPHORUS AND SULPHUR ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF SAU SARISHA 1 (*Brassica campestris* L.)

BY

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CERTIFICATE

This is to certify that "**EFFECT OF PHOSPHORUS AND SULPHUR ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF SAU SARISHA1 (*Brassica campestris* L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY**, embodies the result of a piece of bona fide research work carried out by **MD. SAROWAR HOSSAIN,** Registration No. 27569/00730 under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Prof. Dr. Md. Hazrat Ali)
Supervisor

Dated: 26.12.2007
Dhaka, Bangladesh

Dedicated To My

Beloved Parents

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EFFECT OF PHOSPHORUS AND SULPHUR ON THE YIELD AND YIELD CONTRIBUTING CHARACTERS OF SAU SARISHA 1 (*Brassica campestris* L.)

ABSTRACT

An experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2006 to March 2007 to study the effect of phosphorus and sulphur singly and also combined on the yield and yield contributing characters of SAU Sarisha 1 (*Brassica campestris* L.). The experiment included four levels of phosphorous viz., 0, 30, 60 and 90 kg P_2O_5 kg ha^{-1} as well as four levels of sulphur viz., 0, 10, 20 and 30 kg S ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. Phosphorous showed significant effect on yield and yield attributes of rapeseed except the number of branches $plant^{-1}$. Application of phosphorus @ 60 kg ha^{-1} produced the highest seed yield, plant height, siliqua $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000-seed weight, stover yield, biological yield and harvest index. In all the cases lower response was found from the control treatment. Sulphur fertilizer also had significant effect on yield and yield attributes of rapeseed except branches $plant^{-1}$ and siliqua length. Application of sulphur @ 20 kg ha^{-1} gave the highest seed yield, plant height, pods $plant^{-1}$, seeds pod^{-1}, 1000-seed weight, stover yield, biological yield and harvest index. But in all cases the lower response was found from the control treatment. Sulphur @ 20 kg ha^{-1} was found statistically superior to all other treatments.

Phosphorus in combination with sulphur showed significant effect on yield and yield attributes of rapeseed except branches $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$ and 1000-seed weight. Phosphorus @ 60 kg and sulphur @ 20 kg ha^{-1} resulted the highest seed yield, plant height, stover yield, biological yield and harvest index. But in all the cases lower response was found from the control treatment.

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Chapter I
Introduction

CHAPTER-I

INTRODUCTION

Rapeseed-mustard (*Brassica* spp.) are important edible oil crops of Bangladesh. For rapeseed and mustard, the term mustard and sarisha are commonly used. It tops the list in respect of area and production among the oil crops grown in Bangladesh. Every year rapeseed and mustard cover about 3.40 lac hectares of land their production is about 2.46 tons of seeds.

Rapeseed-mustard is important oil seed crops in Bangladesh. It accounts about 72 % of total oilseed production in the country. The area under rapeseed and mustard is 0.30 million hectares which is about 80 % of the total oilseed area. But the area under mustard is declining due to late harvesting of high yielding T. aman rice and increased cultivation of boro rice. Since last ten years there is a gradual decline in an area of 104 thousand hectare and production 68 thousand tons of rapeseed-mustard (Anon. 2006). Though the production of edible oil is being decreased, but the demand is increasing day by day with the increasing population. The present domestic edible oilseed production is 267 thousand tons which meets only one third of national demand (Anon. 2006).

From time immemorial, rapeseed oil plays an important role as a fat substitute in our daily diet. This widely used as cooking ingredient. Moreover, mustard oil cake is not only used as a feed for cattle and fish but also used as good manure. Bangladesh has been in short of 65-70% of the demand of the edible oil. As a result, a huge amount of foreign currency is being drained out every year for importing oil and oil seeds from abroad. The competition of rapeseed with other food grain has shifted the cultivation of rapeseed to marginal lands of poor productivity. In view of population growth the edible oil demand is increasing day by day. It is, therefore, highly expected that production of edible oil should be increased considerably to fulfill the demand. But there is a general consensus that increasing yield is the most reasonable way to increase production. The average yield of rapeseed in Bangladesh is very low (0.812 t ha^{-1}) compared to that of other countries of the world. The average yield of rapeseed in Germany, France, UK, Poland, China and Japan is 3.70, 2.75, 2.85, 2.6, 1.8 and 1.6 t ha^{-1}, respectively (FAO, 2006). The major reason for such yield of rapeseed in Bangladesh may be due to cultivation of rapeseed with imbalance or in-some cases without fertilizers. One of the most important reasons of the low yield of rapeseed may be due to gradual decrease of the productivity of oil caused by continuous cultivation and shifting the cultivation of rapeseed to marginal land due to competition with food grains. The soil of Bangladesh is deficient in phosphorus and sulphur.

SAU Sarisha 1 is the newly released variety of Sher-e-Bangla Agricultural University. It is a short term and high yielding variety of sarisha. It is under yellow Sarson group of the species of *campestris*. From the fertilizer recommendation that given in the leaf let of SAU Sarisha 1 it is found that sulphur and phosphorous is the important two nutrient affecting yields and yield contributing characters of this variety.

Rapeseed is highly sensitive to phosphorus and this element has tremendous influence on both growth and yield of rapeseed. The literature shows that phosphorus has significant effect on plant height, branches per plant, and pods per plant and other growth factors and yield of mustard (Arthamwar *et al.*, 1994; Patel and Shelke, 1999). Sulphur as an important nutrient element for the cultivation of rapeseed plays a vital role in increasing the yield by improving yield components including the oil content (Dudey and Khan, 1991; Singh and Bairathi, 1980).

Phosphourus and sulphur fertilizers are considered to be very important in enhancing the production of rapeseed in Bangladesh. A very few research have so been done with combined application of phosphorus and sulphur in rapeseed. Therefore, the present piece of work was undertaken to study the effect of phosphorus and sulphur on the yield and yield components of the recently released rapeseed cultivar SAU Sarisha 1.

This experiment was undertaken keeping the following objectives in mind:

1. Find out the effect of Phosphorus on the yield of SAU Sarisha 1
2. Evaluate the effect of sulphur on the yield of SAU Sarisha 1
3. Study the interaction effect of phosphorus and sulphur on the yield of SAU Sarisha 1.

Chapter II
Review of Literature

CHAPTER –II

REVIEW OF LITERATURE

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

2.1 Plant height

2.1.1 Effect of phosphorous

Patel and Shelke (1999) observed that application of phosphorus significantly increased the yield parameters (plant height), seed and stover yield, oil and protein content and net return up to 80 kg P_2O_5 ha^{-1}.

Ram *et al.* (1999) reported that application of 15 kg P_2O_5 significantly increased plant height, number of siliquae $plant^{-1}$, seed $siliqua^{-1}$, length of siliqua and least weight over the control (no P) but the number of primary and secondary branches were higher with 30 kg P_2O_5 ha^{-1}. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg or no P.

Patel and Shelke (1998) revealed that the growth, yield attributes as well as stover yield of Indian mustard increased significantly with the application of farm yard manures (5 t ha^{-1}) over the control. Application of P showed linear increase of these characters up to 80 kg P_2O_5 ha^{-1}, similarly all these parameters also increased significantly with increasing levels of sulphur up to 60 kg ha^{-1}.

2.1.2 Effect of sulphur

Chaudhury *et al.* (1991a) conducted a field experiment with Varuna mustard during 1988-89. The treatments comprising 3 levels of S (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters except 1000-seed weight were influenced significantly up to the highest level of N (80 kg N ha^{-1}). Sulphur increased plant height and ultimately seed yield ha^{-1}. Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg ha^{-1}.

2.1.3 Interaction effect of phosphorus and sulphur

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

Singh *et al.* (1998) conducted an experiment during winter (Rabi) season 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes and yield. Application of 120 kg N + 60 kg P_2O_5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased the plant height.

Tomar *et al.* (1997a) performed an experiment to determine the effect of N (60, 80 and 120 kg ha^{-1}), phosphorus (0, 40 and 80 P_2O_5) and sulphur (0, 40 and 80 kg S ha^{-1}) fertilization. They observed that the growth attributes (plant height) increased significantly with the increasing levels of N, P and S up to 120, 80 and 80 kg ha^{-1}, respectively.

2.2 Branches plant^{-1}

2.2.1 Effect of phosphorous

Ram *et al.* (1999) found that the number of primary and secondary branches were maximum with 30 kg P_2O_5 ha^{-1}. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg or no P.

Patel and Shelke (1999a) observed that application of phosphorus significantly increased the number of branches plant^{-1} and net return up to 80 kg P_2O_5 ha^{-1}.

Patel and Shelke (1998) revealed that the growth, yield attributes as well as stover yield of Indian mustard increased significantly with application of farm yard manures (5 t ha^{-1}) over the control. Application of P showed linear increase of these characters up to 80 kg P_2O_5 ha^{-1}, similarly all these parameters also increased significantly with increasing levels of sulphur up to 60 kg ha^{-1}.

2.2.2 Effect of sulphur

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

Chaudhury *et al.* (1991b) conducted a field experiment with Varuna mustard during 1988-89. The treatments comprising 3 levels of S (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters influenced significantly except 1000-seed weight up to the highest level of N (80 kg N ha^{-1}). Sulphur increased plant height, seeds siliqua^{-1}, seed weight plant^{-1} and ultimately seed yield ha^{-1}. Maximum seed yield was recorded at the highest S level which was significantly superior to 0 and 50 kg ha^{-1}.

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

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

2.2.3 Interaction effect of phosphorus and sulphur

Davaria *et al.* (2001a) worked with the treatments of P at 0, 25 and 50 kg and S at 0, 25, 50 and 100 kg $ha^{-1}$and S at 0, 25, 50 and 100 kg ha^{-1}. In the P treatments, number of primary branches and secondary branches $plant^{-1}$ were highest with 50 kg P_20_5 ha^{-1}. S had no significant effects on growth yield, except for seed yield, which was highest at 50 and 10 kg ha^{-1}.

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

Singh *et al.* (1998b) conducted an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P2O5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased the number of branches.

Tomar *et al.* (1997b) performed an experiment to determine the effect of N (60, 80 and 120 kg ha^{-1}), phosphorus (0, 40 and 80 P_2O_5) and sulphur (0, 40 and 80 kg S ha^{-1}) fertilization. They observed that the growth attributes (branches $plant^{-1}$)

increased significantly with the increasing levels of N, P and S up to 120, 80 and 80 kg ha^{-1}, respectively.

Singh and Kumar (1994) observed that sulphur @ 40 kg ha^{-1} significantly increased the growth, yield contributes and yield of Indian mustard compared with 0 and 20 kg S ha^{-1}.

2.3 Siliquae plant^{-1}

2.3.1 Effect of phosphorous

Singh (2002) observed that application of N and P increased the length of siliqua, number of siliquae plant^{-1}, seeds siliqua^{-1} seed yield and 1000-seed weight. Significant increase in yield and yield components were recorded in 60, 90 and 120 kg N ha^{-1} and 30, 45 and 60 kg P ha^{-1} treatments. Maximum seed yield was recorded from application of 45 kg P ha^{-1} & 120 kg N ha^{-1}.

Ram *et al.* (1999) reported that application of 15 kg P_2O_5 significantly increased number of siliqua plant^{-1}, seed siliqua $^{-1}$ and lowest weight over the control (no P) but the number of primary and secondary branches was maximum with 30 kg P_2O_5 ha^{-1}. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg and control.

2.3.2 Effect of sulphur

Chaudhury *et al.* (1991b) carried out a field experiment with Varuna mustard during 1988-89. The treatments comprising 3 levels of S (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters were influenced significantly except 1000-seed weight up to the highest level of N (80 kg N ha^{-1}). Sulphur increased plant height, siliquae plant^{-1}and seeds siliqua^{-1}. Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg ha^{-1}.

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

2.3.3 Interaction effect of phosphorus and sulphur

Davaria *et al.* (2001b) worked with the treatments of P at 0, 25 and 50 kg and S at 0, 25, 50 and 100 kg ha^{-1}and S at 0, 25, 50 and 100 kg ha $^{-1}$. In the P treatments, siliqua plant^{-1} was highest with 50 kg P_20_5 ha^{-1}.

Singh *et al.* (1998a) conducted an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P_2O_5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased the number of siliquae plant^{-1}.

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

2.4 Siliqua length

2.4.1 *Effect of phosphorous*

Singh (2002) observed that application of N and P increased the length of siliqua, number of siliquae plant^{-1}, seeds siliqua^{-1} and seed yield. Significant increase in yield and yield components were recorded in 60, 90 and 120 kg N ha^{-1} and 30, 45 and 60 kg P ha^{-1} treatments. Maximum seed yield was recorded from application of 45 kg ha^{-1} and 120 kg N ha^{-1}.

Ram *et al.* (1999) reported that application of 15 kg P_2O_5 ha^{-1} significantly increased plant height, number of siliqua plant^{-1}, seed siliqua $^{-1}$, length of siliqua and least weight over the control but the number of primary and secondary branches was higher with 30 kg P_2O_5 ha^{-1}. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg and control.

2.4.2 Effect of sulphur

Chaudhury *et al.* (1991b) conducted a field experiment with Varuna mustard during 1988-89. The treatments comprising 3 levels of S (0, 25 and 50 kg S ha^{-1}). All yield contributing characters except 1000-seed weight influenced significantly up to the highest level of N (80 kg N ha^{-1}). Sulphur increased plant height, seeds siliqua^{-1}, seed weight plant^{-1} and ultimately seed yield ha^{-1}. Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg ha^{-1}.

2.4.3 Interaction effect of phosphorus and sulphur

Tomar *et al.* (1997b) carried out an experiment with N (60, 80 and 120 kg ha^{-1}), phosphorous (0, 40 and 80 P_2O_5) and sulphur (0, 40 and 80 kg S ha^{-1}) fertilization and noticed that siliqua length increased significantly with the increasing levels of N, P and S up to 120, 80 and 80 kg ha^{-1}, respectively.

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

2.5 Seeds $siliqua^{-1}$

2.5.1 Effect of phosphorous

Singh (2002) observed that application of N and P increased the length of siliqua, number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$ 1000-seed weight and seed yield. Significant increase in yield and yield components were recorded in 60, 90 and 120 kg N ha^{-1} and 30, 45 and 60 kg P ha^{-1} treatments. Maximum seed yield was recorded with the application of 45 kg P ha^{-1} and 120 kg N ha^{-1}.

Ram *et al.* (1999) reported that application of 15 kg P_2O_5 significantly increased plant height, number of siliquae $plant^{-1}$, seed siliqua $^{-1}$, length of siliqua and lowest weight over the control (no P) but the number of branches was higher with 30 kg P_2O_5 ha^{-1}.

2.5.2 Effect of sulphur

Chaudhury *et al.* (1991b) conducted a field experiment with Varuna mustard during 1988-89. The treatments comprising 4 levels of S (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters except 1000-seed weight were influenced significantly up to the highest level of N (80 kg N ha^{-1}). Sulphur increased seeds $siliqua^{-1}$, seed weight $plant^{-1}$ and ultimately seed yield ha^{-1}. Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg S ha^{-1}.

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

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

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

BARI (1982) reported that application of S was favourable for the production of more seeds siliqua^{-1} in comparison to plants not fertilized without sulphur.

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

2.5.3 Interaction effect of phosphorus and sulphur

Davaria *et al.* (2001a) carried out an experiment with P at 0, 25 and 50 kg and S at 0, 25, 50 and 100 kg ha^{-1}and S at 0, 25, 50 and 100 kg ha $^{-1}$. In the P treatments @ 50 kg P_20_5 ha^{-1} seeds sliqua^{-1} was highest in combination with at 50 and 10 kg S ha^{-1}.

2.6 1000 seed weight

2.6.1 Effect of phosphorous

Singh (2002) observed that significant increase in yield and yield components were recorded at 60, 90 and 120 kg N and 30, 45 and 60 kg P ha^{-1} treatments. Maximum seed yield was recorded from application of 45 kg P ha^{-1} and 120 kg Nha^{-1}.

Ram *et al.* (1999) reported that application of 15 kg P_2O_5 t ha^{-1}significantly increased 1000 seed weight over the control but the number of primary and secondary branches was higher with 30 kg P_2O_5 ha^{-1}. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg and control.

2.6.2 Effect of sulphur

The highest yield was recorded for oilseed rape fertilized with 40 kg S ha^{-1} cultivated on plots of low sulphur content, and the yield and seed weight obtained was 65% higher than that from control objects (poor in sulphur). A weak reaction of oilseed rape to fertilization with sulphur which coincided with a good sulphur supply was observed by Evans *et al.* (1991). Scarce research into the effect of sulphur on spring oilseed rape showed that as for soil of low sulphur content (14.3 mg S-SO_4 kg^{-1} of soil) fertilization with a dose of 12 kg S ha^{-1} increased the seed yield from 8.14 to 14.7% as compared with the yield from non-fertilized plants (Krauze and Bowszys, 2001). They stated that spring oilseed rape shows a lower increase in seed yield due to sulphur fertilization applied than traditional and double-low winter oilseed rape cultivars.

2.6.3 Interaction effect of phosphorus and sulphur

Davaria *et al.* (2001b) in an experiment with the treatments of P at 0, 25 and 50 kg and S at 0, 25, 50 and 100 kg $ha^{-1}$and S at 0, 25, 50 and 100 kg ha^{-1} found that in the P treatments (50 kg P_20_5 ha^{-1}), 1000-seed weight was highest with 50 and 10 kg S ha^{-1}.

Singh *et al.* (1998a) conducted an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P_2O_5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased the plant height, number of branches, pods $plant^{-1}$, 1000-seed weight, seed and stover yields.

Tomar *et al.* (1997b) carried out an experiment to find out the effect of N (60, 80 and 120 kg ha^{-1}), phosphorous (0, 40 and 80 P2O5) and sulphur (0, 40 and 80 kg S ha^{-1}) fertilization. They observed that the 1000-seed weight increased significantly with the increasing levels of N, P and S up to 120, 80 and 80 kg ha^{-1}, respectively.

2.7 Seed yield

2.7.1 Effect of phosphorous

Poonia *et al.* (2002) conducted an experiment with three sources of phosphorous (gypsum, single super phosphate and diamonium phosphate) and three levels of phosphorus (20, 40 and 60 kg P_2O_5) result showed that the application of phosphorus through diamonium phosphate at 40 kg P_2O_5 ha^{-1} significantly increased the seed yield and oil yield of Indian mustard.

Singh (2002) observed that application of N and P increased the length of siliqua, number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$ seed yield and 1000-seed weight. Significant increase in yield and yield components were recorded in 60, 90 and 120 kg N ha^{-1} and 30, 45 and 60 kg P ha^{-1} treatments. Maximum seed yield was recorded with the application of 45 kg P ha^{-1} and 120 kg N ha^{-1}.

Ram *et al.* (1999) found that application of 15 kg P_2O_5 significantly increased seed yield and the lowest weight over the control. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg P_2O_5 ha^{-1} and control.

Singh *et al.* (1999) revealed that seed yield of Indian mustard (*Brassica juncea*) increased up to 30 kg phosphorus ha^{-1}, where Patel and Shelke (1999) observed that application of phosphorous significantly increased the yield parametres, seed and stover yield, oil and protein and net return up to 80 kg P_2O_5 ha^{-1}.

Aulakh and Paricha. (1998) reported that groundnut responded to an application of P_2O_5 up to 20 kg P_2O_5 ha^{-1} when the preceding mustard crop did not receive fertilizer P. However, when the mustard received 40 kg P_2O_5 ha^{-1}, the succeeding groundnut crop did not respond to additional P applied to it, but obtained the required P from that which was in the soil including the residue from the previous application. The mustard crop responded significantly (46%) to P up to 40 kg P_2O_5 ha^{-1} but there was a much less response (13–27%) to residual P that was applied to the preceding groundnut. The differences between these two crops are due to differences in climate between the mustard and groundnut growing seasons and corresponding differences in soil conditions, and perhaps also to differences in the P-solubilizing abilities of the two crops. The results suggest that in groundnut–mustard rotations grown under these climatic conditions, a direct application of 40 kg P_2O_5 ha^{-1} to mustard would be sufficient to meet the P needs of both the crops. This would be the most efficient way of using fertilizer P, increasing P recovery and improving total biomass partitioning to mustard seed or groundnut pod yield.

Arthamwar *et al.* (1994) reported that every increase in the level of phosphorous (0, 40 and 80 kg P2O5 ha^{-1}) significantly improved all the attributes, seed yield, oil content and oil yield of Indian mustard.

Reddy and Sinha (1988) observed that application of N and P increased the seed yield of mustard linearly up to 30 kg P ha^{-1}.

2.7.2 Effect of sulphur

The foliar fertilisation of oilseed rape with ionic sulphur and soil fertilisation with elemental sulphur in the present research increased the content of glucosinolates in seeds proportionally to the dose applied. The highest total content of glucosinolates (12.8 $\mu M \cdot g^{-1}$ of dry matter), including the sum of alkenyl glucosinolates (7.48 $\mu M \cdot g^{-1}$ of dry matter), was recorded in seeds of plants when soil was fertilised with elemental sulphur at the dose of 60 $kg \cdot ha^{-1}$. A varied level of glucosinolates in seeds affects the pathogen-plant relationship. As shown by Trzciński (2001) and Drozdowska *et al.* (2002), the seeds collected from objects where soil was fertilised with elemental sulphur at 60 kg ha^{-1} were least infected by pathogenic fungi.

Scarce research into the effect of sulphur on spring oilseed rape showed that as for soil of low sulphur content (14.3 mg $S\text{-}SO_4 \cdot kg^{-1}$ of soil) fertilisation with a dose of 12 kg S ha^{-1} increased the seed yield from 8.14 to 14.7% as compared with the yield from non-fertilised plants (Krauze and Bowszys, 2001). The results, as well as the present results, state that spring oilseed rape shows a lower increase in seed yield due to sulphur fertilisation applied than traditional and double-low winter oilseed rape cultivars.

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

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

The present research showed that 'Star' spring oilseed rape cultivated on soil of a low content of sulphur reacted with the highest increase in yield to foliar fertilisation with elemental sulphur at the dose of 60 kg ha^{-1}. The content of glucosinolates in seeds collected from that object (10.8 $\mu M \cdot g^{-1}$ of dry matter) was comparable with the control (11.9 $\mu M\ g^{-1}$ of dry matter) and with the results reported by COBORU (10.0 $\mu M \cdot g^{-1}$ of dry matter) (Wałkowski, 2000).

Rahmatullah *et al.* (1999) conducted a field experiments on two Alfisols at different locations on Westar and CON-I varieties of *Brassica napus* to S-application (0 and 37 kg ha^{-1}) as ammonium sulphate, gypsum and single superphosphate. Various S-fertilizers, *Brassica* varieties and location of the experiment had a significant ($p<0.05$) main and interactive effect on the grain and oil yield of Brassica. Different S-amendments in increasing grain yield of *Brassica* followed the order: ammonium sulphate > gypsum > single superphosphate. Westar was a better grain-yielding and a more S-responsive variety of *Brassica* than CON-I. Both grain and oil yield of *Brassica* were higher on a site (Fateh Jang) containing low $CaCO_3$ and high plant-available P. Sulphur concentration in seed was found in strong antagonism with seed P.

The highest yield was recorded for oilseed rape fertilised with 40 kg S ha^{-1} cultivated on plots of low sulphur content, and the yield obtained was 65% higher than that from control objects (poor in sulphur). A weak reaction of oilseed rape to fertilisation with sulphur which coincided with a good sulphur supply was observed by Evans *et al.* (1991), Haneklaus *et al.* (1999).

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

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

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

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

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

Khanpara *et al.* (1992b) reported that the entire yield characters and seed yield showed a significant increased up to 100 kg S ha^{-1}. Mode of S application did not show significant effect on yield attributes and seed yield.

Chaudhury *et al.* (1991a) conducted a field experiment with Varuna mustard during 1988-89. The treatments comprising 3 levels of S (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters except 1000-seed weight were influenced significantly up to the highest level of N (80 kg N ha^{-1}). Sulphur increased plant height, siliqua $plant^{-1}$, seeds $siliqua^{-1}$, seed weight $plant^{-1}$ and ultimately seed yield ha^{-1}. Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg S ha^{-1}. Dubey and Khan (1991) also reported that S up to 30 kg ha^{-1} significantly increase the seed yield of mustard.

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

2.7.3 Interaction effect of phosphorus and sulphur

Jaggi (1998) observed that seed yield significantly increased with S application @ 60 kg ha^{-1}. With S addition @ 30, 60 and 90 kg ha^{-1}, increases in seed yield over control were 121, 157 and 176% higher, respectively. Similar increases in seed yield with P_2O_5 application @ 30 and 60 kg ha^{-1} were 36 and 82% higher, respectively. A significant positive interaction between two nutrients in increasing seed and straw yields was observed, giving the highest seed (21.5 q ha^{-1}), and straw

(69.0 q ha^{-1}) yields due to combine application of sulphur and P_2O_5 at their maximum rates (S 90, P_2O_5 60 kg ha^{-1}).

Jaggi and Sharma (1997) conducted an experiment to study the effect of four levels of sulphur (0, 30, 60 and 90 kg S ha^{-1}) and three phosphorous (0, 13.1 and 26.2 kg ha^{-1}) on Indian mustard. A significant response of crop was observed up to its application of 60 kg S ha^{-1} in seed and 30 kg S ha^{-1} in straw yield. However, crop responded up to 26.2 kg P ha^{-1}. Maximum seed (21.5 q ha^{-1}) and straw (69.0 q ha^{-1}) yields were recorded from the treatment combination of P 26.2 + S 90 kg ha^{-1}.

2.8 Stover yield

2.8.1 Effect of phosphorous

Patel and Shelke (1999) observed that application of phosphorous significantly increased the number of branches $plant^{-1}$, seed and stover yield, oil and protein content and net return up to 80 kg P_2O_5 ha^{-1}. Ram *et al.* (1999) also reported that application of 15 kg P_2O_5 ha^{-1} significantly increased stover yield but the number of primary branches, secondary branches and stover yield was higher with 30 kg P_2O_5 ha^{-1}. The seed and straw yields were increased by 30 kg P_2O_5 ha^{-1} compared with 15 kg P_2O_5 and control.

2.8.2 Effect of sulphur

Trzciński (2001) found that application of 60 kg S significantly increased stover yield. The seed and straw yields were increased by 60 kg P_2O_5 ha^{-1} compared with 15 kg or no S.

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

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

2.8.3 Interaction effect of phosphorus and sulphur

Singh *et al.* (1998a) conducted an an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P2O5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased the plant height, number of branches, pods $plant^{-1}$, 1000-seed weight, seed and stover yield.

Singh *et al.* (1998b) conducted an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P2O5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased seed and stover yield.

2.9 Biological yield

2.9.1 Effect of phosphorous

Poonia *et al.* (2002) conducted an experiment with three sources of phosphorous (gypsum, single super phosphate and diamonium phosphate) and three levels of phosphorus (20, 40 and 60 kg P_2O_5) result showed that the application of phosphorus through diamonium phosphate at 40 kg P_2O_5 ha^{-1} significantly increased the seed yield, biological yield and oil yield of Indian mustard over 20 kg P_2O_5 ha^{-1} but was at per with application of 60 kg P_2O_5 ha^{-1}.

2.9.2 Effect of sulphur

Sudhakar *et al.* (2002) studied the effect of sulphur (20, 40 and 60 kg ha^{-1}) on the performance of Indian mustard cv. Varuna. Sulphur was applied as ammonium sulphate as basal and observed gradual increase of biological yield of sulophur levels.

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

2.9.3 Interaction effect of phosphorus and sulphur

Chandel *et al.* (2002) studied the effect of phosphorus and sulphur applied to rice and mustard grown in sequence, showed that S application to mustard significantly improved biological yield in following seasons up to 40 kg $P_2O_5ha^{-1}$.

Singh *et al.* (1998a) conducted an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P_2O_5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased the stover and biological yield and harvest index.

2.10 Harvest index

2.10.1 Effect of phosphorous

Singh (2002) observed that maximum seed yield and harvest index was recorded from application of 45 kg P ha^{-1} and 120 kg N ha^{-1}.

2.10.2 Effect of sulphur

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

2.10.3 Interaction effect of phosphorus and sulphur

Singh *et al.* (1998) carried out an experiment during winter (Rabi) season of 1994-95 and 1995-96 with Indian mustard (*Brassica juncea*) to study the effect of different fertility and sulphur levels on growth attributes, yields. Application of 120 kg N + 60 kg P2O5 + 10 kg Zn + 90 kg S ha^{-1} significantly increased biological yield, seed & stover yields and harvest index.

Chapter III
Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiments was conducted at the Agronomy Field of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from 17 November 2006 to 3 March 2007. Details of different materials used and methodology followed for conducting this experiment have been presented in this chapter.

3.1. Soil and site

The experiment was laid out in the non calcarious dark grey floodplain soil of Sher-e- Bangla Agricultural University, Sher-e- Bangla Nagar, Dhaka. This soil belongs to the Modhupur tract under AEZ 28. The selected plot was medium high land and the soil series was Tejgaon series. The soil characteristics was clay loam in texture with pH value 5.55 and C:N ratio 8:1. The site of the experimental plot is in the $23^{0}74$ N latitude and $90^{0}35$ E longitude with an elevation of 8.2 m above sea level (Anon, 1989).

3.2 Climate

Experimental site was located on the sub-tropical zone where rainfall is maximum during the Kharif season (April to September). The rainfall is scanty in association with moderately low temperature and plenty of sunshine in the Rabi season (October to March). The materiological data recorded at the whether Yard during November 2006 to February 2007 are presented in Appendix ii.

3.3 Variety used

SAU Sarisha 1 a high yielding variety under yellow sarsan group of *Brassica campestris* developed by the Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University was used for the experiment. Before sowing, germination test was carried out in the laboratory and percentage of germination was found to be over 90 %.

3.4 Fertilizer treatments under investigation

a. Rates of phosphorus (P_2O_5): 4

i) 0 kg ha^{-1} (P_0)

ii) 30 kg ha^{-1} (P_1)

iii) 60 kg ha^{-1} (P_2)

iv) 90 kg ha^{-1} (P_3)

b. Rates of sulphur : 4

i) 0 kg ha^{-1}(S_0)

ii) 10 kg ha^{-1}(S_1)

iii) 20 kg ha^{-1}(S_2)

iv) 30 kg ha^{-1}(S_3)

3.5 Lay out of the experiment

The experiment was laid out in a Randomized Complete Block Design (factorial) with three replications. There were sixteen fertilizer treatments and total number of experimental plots were 48 (16x3). The size of each plot was 6 m^2 (3.0 m x 2.0 m). The blocks were separated from one another by 1 (one) m width. The distance between the plots was 0.5 m. Allocation of all the treatments was made at random in each block.

3.6 Land preparation

The land preparation was done with power tiller and country plough. Ploughed soil was then brought into fine tilth condition by four operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed. The first ploughing and final land preparation were done on 15 November and 16 November 2006, respectively. The plots were laid out in the field on 17 November 2007.

3.7 Soil sampling

Three composite soil samples were collected from plough depth (0-15 cm) of soil profile, taking one from each block before first ploughing. Each composite sample was a mixture of 10 separate samples obtained from 10 different spots in each block. The samples were collected, air dried and ground to pass through a 10 mesh sieve and stored in polythene bags for analysis in laboratory (Appendix i).

3.8 Applications of fertilizers

The S and P were applied in the form of gypsum and murate of potash (MP) containing 18% S and 60% K_2O, respectively. Full dose of gypsum and murate of potash (MP) were applied during the final land preparation as basal dose.

3.9 Sowing of seeds

The seeds at the rate of 8 kg ha^{-1} (SAU Sarisha 1) were sown in rows 30 cm apart by hand. After sowing, the seeds were covered with soil and slightly pressed by hand. The seeds were sown on 17 November 2006. Sowing was done at suitable condition of soils, which ensured satisfactory germination of seeds. The seeds germinated after 5 days of sowing.

3.10 Weeding and thinning

Two weedings and thinnings were done at 12 and 25 days after sowing so to say on 29 November 2006 and 12 December 2006, respectively. The field was kept weed free all the time during the experimentation. Thinning was done in all unit plots carefully to maintain a uniform plant population $plot^{-1}$.

3.11 Irrigation and insecticide application

Two irrigations were given once on 17 December 2006 and 05 January 2007, respectively after 30 days and 48 days of sowing in order to maintain enough moisture in the field. There was scanty rainfall in the period of cultivation of the crop. The crop was found infested with aphids at the time of flowering and it was controlled successfully by Malathion 57 @ 2 ml L^{-1}.

3.12 Sample collection and harvesting and threshing

When around 80 % of the siliquae in terminal raceme turned golden yellow in colour, crops were harvested. The crop maturity varied with fertilizer treatments. Collection of sample was done as per required. Samples were collected randomly i.e. from different places of each plot leaving undisturbed one meter square in the centre. After collection of sample, harvesting and threshing were done on 04 to 07 March 2007. The harvested crops were tied in to bundles and carried to the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.13 Collection of experimental data

For the convenience of collecting data, ten sample plants $plot^{-1}$ were selected at random. The sample plants were uprooted prior to harvest and dried properly in the sun before collecting data. The seed and straw yield $plot^{-1}$ were recorded after cleaning and drying them properly in the sun. The procedures followed to collect the data for different characters are given below.

3.14 Plant height (cm)

The height of the plants was measured from the ground level to the tip of the topmost siliqua.

3.15 Branches plant^{-1}

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

The ten tagged plants in each plot were also used for counting the number of secondary branches at harvest .

3.16 Siliquae plant^{-1}

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

3.17 Seeds siliqua^{-1} The number of seeds was counted by splitting ten siliqua plant^{-1}.

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

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

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

Before threshing ,the total biological yield from the net area was recorded .Later , the stover per net area of each plot was obtained by deducting the seed yield per plot from the biological yield (seed+stover) per plot and used to compute the stover yield in t ha^{-1} .

3.20 1000-seed weight (g)

Thousand seeds of each plot were counted and weighed with a fine electric balance.

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

The summation of grain yield and straw yield was considered as biological yield.

3.22 Harvest index (%)

The harvest index (HI) was calculated by dividing the actual yield of seeds the biological yield of the crop. It was expressed as percentage.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.23 Statistical analysis

Analysis of variance of the results on the various crop characters was performed and their significant mean differences were adjudged by Least Significant Difference (LSD) (Gomez and Gomez, 1984).

Chapter IV
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study have been discussed in this chapter. The growth and yield components including plant height, branches plant^{-1}, siliqua number plant^{-1}, siliqua length, seeds siliqua^{-1}, 1000 seed weight, seed yield, stover yield, biological yield and harvest index are presented in Table 1, 2, and 3. The detailed experimental findings are explained and discussed below with supporting references wherever possible.

4.1 Plant height (cm):

4.1.1 Effect of phosphorus

Application of phosphorus fertilizer significantly increased the plant height (Table 1). The tallest plant (105.1 cm) was recorded from phosphorous at the rate of 60 kg P_2O_5 ha^{-1}. But the shortest plant (96.54 cm) was recorded from control treatment. This agreed with those of Tomar *et al.* (1997) who observed that the plant height increased significantly up to 80 kg P_2O_5 ha^{-1}.

4.1.2 Effect of sulphur

Application of sulphur fertilizer did not significantly increased plant height (Table 2). The treatment of sulphur at the rate of 20 kg S ha^{-1} produced the tallest plant height (105.10 cm) which was statistically similar to 10 kg S ha^{-1}. But the shortest plant height was recorded from control treatment (98.57 cm).

4.1.3 Interaction effect of phosphorus and sulphur

It was noticed that treatment combinations of phosphorus and sulphur had significant effect on plant. All the interaction treatments showed statistically similar values with each other (Table 3).

Table 1. Effect of Phosphorous on the plant, yield and yield contributing characters of SAU Sarisha 1

Level of phosphorous (P_2O_5kg ha^{-1})	Plant height (cm)	Branches $plant^{-1}$	Siliqua length (cm)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
0	96.54	3.14	5.69	2.78	3.68	24.56
30	104.5	3.99	6.14	3.22	4.38	27.02
60	105.1	4.85	6.31	3.35	4.61	27.93
90	103.90	4.22	6.03	3.28	4.47	26.72
LSD 0.05	10.81	0.30	1.67	0.86	0.71	0.48
CV (%)	6.33	4.52	16.61	16.32	9.98	3.01

4.2 Branches $plant^{-1}$:

4.2.1 Effect of phosphorus

From Table 1, it was exhibited that different treatments of phosphorus fertilizer had significant influence on branches $plant^{-1}$. However, the highest number of branches $plant^{-1}$ (4.85) was recorded from the rate of 60 kg ha^{-1} and the lowest branches $plant^{-1}$ (3.14) at control treated plot (Table 1).

4.2.2 Effect of sulphur

From Table 2, it was visualized that different treatments of sulphur fertilizer showed significant influence on branches $plant^{-1}$. However, the highest number of branches $plant^{-1}$ (4.47) was recorded from the rate of 20 kg S ha^{-1} and the lowest branches $plant^{-1}$ (3.42) at control treatment (Table 2).

4.2.3 Interaction effect of phosphorus and sulphur

It was recorded that the interaction effect of 60 kg P_2O_5 and 20 kg S ha^{-1} gave the maximum number of branches $plant^{-1}$ (6.93) (Table 3). The interaction of 30 kg P_2O_5 and 10 kg S ha^{-1} gave the second highest number of branches $plant^{-1}$, also the interaction of 60 kg P_2O_5 and 30 kg S ha^{-1} gave the statistically similar number of branches $plant^{-1}$. Control treatment gave the lowest number of branches $plant^{-1}$. But rest of the interaction treatments showed similar values with each other.

4.3 Siliquae $plant^{-1}$:

4.3.1 Effect of phosphorus

Trend of formation of siliquae $plant^{-1}$ due to application of different levels of phosphorus was similar that observed in plant height. The highest number of siliqua $plant^{-1}$ (169.5) was found from 60 kg P_2O_5 ha^{-1} and the lowest number of siliquae plant (92.31) was obtained from the control treatment. Tomar *et al.* (1997) observed that siliquae $plant^{-1}$ increased significantly up to 80 kg P_2O_5 ha^{-1} and Davaria (2001) obtained the highest number of siliquae $plant^{-1}$ with 50 kg P_2O_5 ha^{-1} which is in agreement with these results.

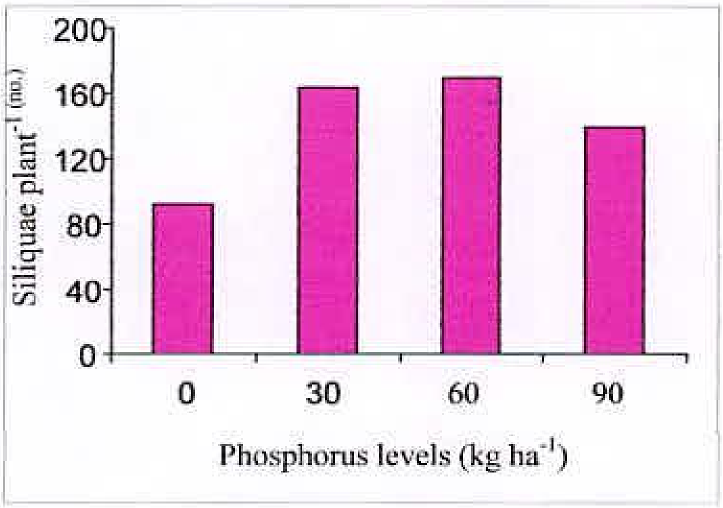

Fig. 1. Effect of phosphorus on siliquae $plant^{-1}$ ($LSD_{0.05}$=11.81)

4.3.2 Effect of sulphur

Sulphur fertilization had significant effect on siliqua $plant^{-1}$. Sulphur at the rate of 20 and 30 kg ha^{-1} produced statistically the highest number of siliqua $plant^{-1}$ and the lowest number of siliquae $plant^{-1}$ (100.60) was produced by control treatment

(Table 2). Koti *et al.* (1989) who obtained significantly highest number of siliquae plant^{-1} applying sulphur at the rate of 20 kg ha^{-1}.

4.3.3 Interaction effect of phosphorus and sulphur

Phosphorus and sulphur interaction showed significant effect on siliquae plant^{-1} (Table 3). The treatment 60 kg P_2O_5 with 20 kg S ha^{-1} produced the highest number of siliqua plant^{-1} (242.3) and control treatment produced the lowest one (85.10).

4.4 Siliqua length (cm):

4.4.1 Effect of phosphorus

Result demonstrated that the application of different levels of phosphorous had no significant effect on siliquae length (cm) of rapeseed (Table 1). Phosphorous fertilizer at the rate of 60 kg ha^{-1} produced the highest siliquae length (6.31 cm). Similar results were obtained by Ram *et al.* (1999) who observed that phosphorous at the rate of 60 kg ha^{-1} P_2O_5 significantly increased siliqua length and Singh (2002) also observed that application of phosphorous increased the length of siliqua of mustard.

4.4.2 Effect of sulphur

It was found from the Table 2 that the siliqua length of rapeseed not significantly increased by different levels of sulphur treatments. However, sulphur fertilizer at the rate of 20 kg ha^{-1} produced the highest siliqua length (6.23 cm) and the control treatment produced the shortest one (5.77 cm).

4.4.3 Interaction effect of phosphorus and sulphur

Phosphorous and sulphur interaction showed significant effect on siliqua length (Table 3). Interaction of phosphorus at 60 and sulphur at 20 kg ha^{-1} produced the maximum siliqua length (7.05 cm).

4.5 Seeds siliqua^{-1}:

4.5.1 Effect of phosphorus

Phosphorus fertilizer had significant effect on seeds siliqua^{-1}. Phosphorus at the rate of 60 kg ha^{-1} produced the highest number of seeds siliqua^{-1} (17.60) which was similar to 90 kg P_2O_5 ha^{-1} but the lowest one (10.99) was obtained from control treatment. A bar graph has been presented in Figure 2 which showed the trend of seed siliqua^{-1} as influenced by different rates of phosphorous. Ram *et al.* (1999) observed that seeds siliqua^{-1} increased significantly at the rate of 15 kg P_2O_5 ha^{-1} and Davaria *et al.* (2001) observed that seeds siliqua^{-1} was highest at the rate of 50 kg P_2O_5 ha^{-1}.

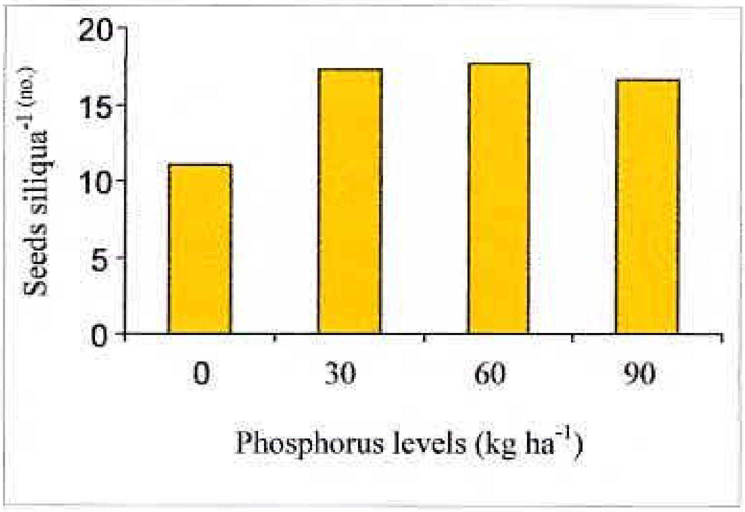

Fig. 2. Effect of phosphorus on seeds siliqua^{-1}($LSD_{0.05}$=3.08)

4.5.2 Effect of sulphur

Different rates of sulphur fertilizer had significant effect on seeds siliqua^{-1}. Sulphur at the rate of 20 kg S ha^{-1} produced the highest number of seeds siliqua^{-1} (18.06) but the lowest one (16.58) was obtained from control treatment (Figure 3). But sulphur treatments at 10 and 30 kg ha^{-1} produced statistically similar number of seeds siliqua^{-1}. Rahman *et al.* (1978) observed that application of sulphur favoured the production of more seeds siliqua^{-1} that supported the present study. A comparative bar graph showed the trends of seeds siliqua^{-1} with different doses of S.

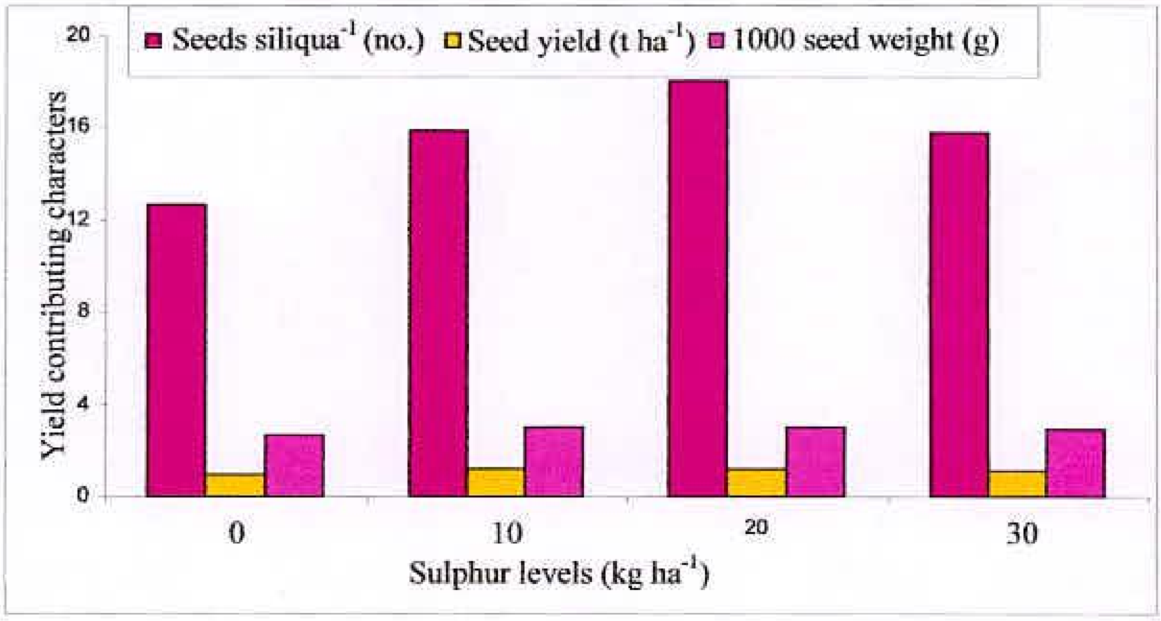

Fig. 3. Effect of sulphur on yield and yield contributing characters

4.5.3 Interaction effect of phosphorus and sulphur

Phosphorus and sulphur interaction had insignificant effect on the seeds siliqua^{-1} (Table 3). The rate of 60 kg P_2O_5 and 20 kg S interaction produced highest number of seeds siliqua^{-1} (21.61). Lowest number of seeds siliqua^{-1} (9.65) was obtained from the control treatment.

4.6 1000 seed weight (g):

4.6.1 Effect of phosphorus

The application of phosphorus significantly influenced 1000 seed weight. Application of 60 kg P_2O_5 ha^{-1} gave the highest 1000- seed weight (3.16 g) which was statistically similar to 30 kg and 90 kg P_2O_5 ha^{-1} where as control treatment gave the lowest (2.53 g) 1000-seed weight (Appendix 1). A bar graph has been presented in Figure 4 which showed the trend of 1000seed weight as influenced by different rates of phosphorus. Davaria *et al.* (2001) observed that phosphorous at the rate of 50 kg P_2O_5 ha^{-1} increased 1000-seed weight.

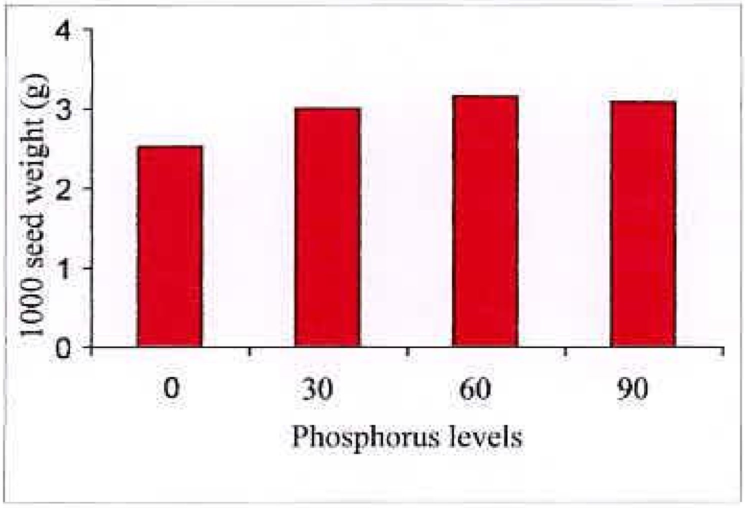

Fig. 4. Effect of phosphorus on 1000 seed weight ($LSD_{0.05}$=0.51)

4.6.2 Effect of sulphur

The application of different rates of sulphur significantly influenced 1000 seed weight. Application of 20 kg S ha^{-1} gave the highest 1000- seed weight (3.06 g) which was statistically similar to 10 kg and 30 kg S ha^{-1} where as control treatment gave the lowest (2.69 g) 1000-seed weight (Figure 3).

4.6.3 Interaction effect of phosphorus and sulphur

It was observed that phosphorus and sulphur interaction had significant effect on 1000-seed weight.

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

4.7.1 Effect of phosphorus

The tend of seed yield (t ha^{-1}) showed a similar response to plant height and number of siliquae $plant^{-1}$ and that the effect was statistically significant. Phosphorous at the rate of 60 kg ha^{-1} gave the highest seed yield (1.28 t ha^{-1}) and seed yield decreased with decreasing or increasing application of phosphorus fertilizer. Seed yield was lowest (0.90 t ha^{-1}) at zero doses of phosphorous. A bar graph has been presented in Figure 4 which showed the trend of seed yield as influenced by different rates of phosphorous. Singh *et al.* (1999) reported that seed yield of Indian mustard increased with 30 kg P ha^{-1}. Davaria *et al.* (2001) also revealed that seed yield was highest with 60 kg P_2O_5 ha^{-1}).

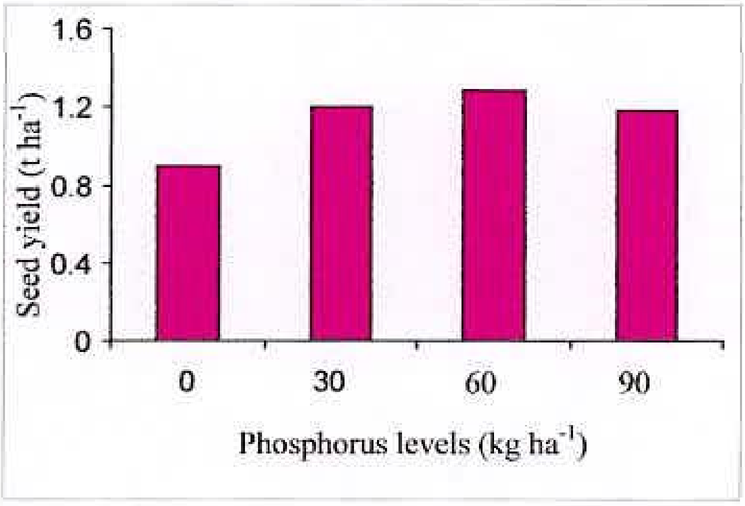

Fig. 5. Effect of phosphorus levels on seed yield ($LSD_{0.05}$=0.48)

4.7.2 Effect of sulphur

Seed yield ha^{-1} showed a similar response to plant height and siliqua plant^{-1} and that the effect was statistically significant (Figure 3). Sulphur at the rate of 20 kg ha^{-1} gave the highest yield (1.25 t ha^{-1}) and the control treatment produced the lowest seed yield (0.92 t ha^{-1}). But on the other hand sulphur treatments at 10 and 30 kg ha^{-1} produced statistically identical seed yield with 20 kg S ha^{-1}. A bar graph has been presented in Figure 3 which showed the trend of seed yield as influenced by different rates of phosphorous. Amin *et al.* (1984) reported that seed yield of rapeseed increased significantly with 20 kg S ha^{-1}.

4.7.3 Interaction effect of phosphorus and sulphur

The treatment combination of phosphorous and sulphur showed significant effect on seed yield (Figure 6). Seed yield was highest (1.79 t ha^{-1}) when 60 kg P_2O_5 and 20 kg S ha^{-1} were applied. The second highest seed yield was observed at 30 kg P_2O_5 and 10 kg S ha^{-1} treatment which was statistically similar to 60 kg P_2O_5 and 10 kg S ha^{-1}, and seed yield was the lowest in the control treatment.

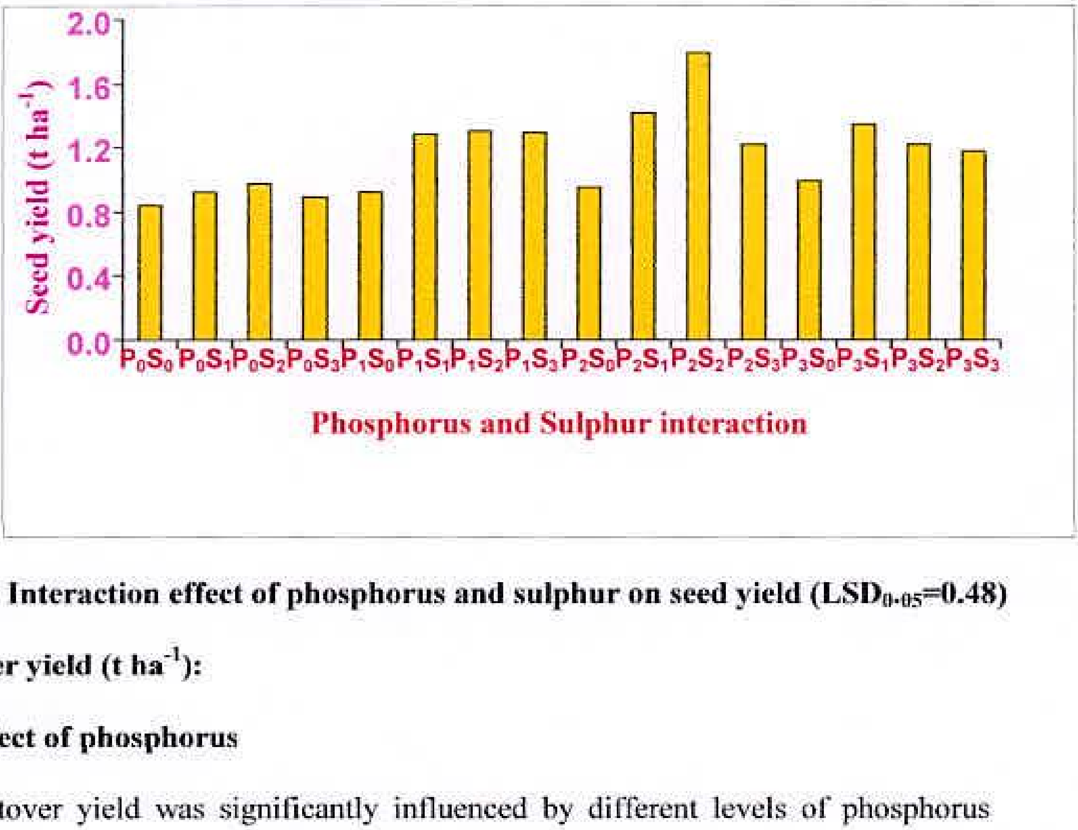

Fig. 6. Interaction effect of phosphorus and sulphur on seed yield ($LSD_{0.05}$=0.48)

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

4.8.1 Effect of phosphorus

Stover yield was significantly influenced by different levels of phosphorus (Table 1). At a rate of 60 kg P_2O_5 ha^{-1} stover yield (3.35 t ha^{-1}) was the highest which was statistically similar to 90 kg P_2O_5 ha^{-1} but the control treatment produced the lowest one (2.78 t ha^{-1}). Patel and Shelke (1999) observed a similar trend of stover yield production.

4.8.2 Effect of sulphur

Stover yield was not significantly influenced by different levels of sulphur (Table 2). However, at a rate of 20 kg S ha^{-1} stover yield (3.43 t ha^{-1}) was the highest but which was statistically similar with 10 and 30 kg S ha^{-1} and the control treatment produced the lowest stover yield (2.87 t ha^{-1}).

4.8.3 Interaction effect of phosphorus and sulphur

Phosphorus and sulphur interaction had significant effect on stover yield (Table 3). The rate of 60 kg P_2O_5 and 20 kg S ha^{-1} gave the highest stover yield (4.21 t ha^{-1}). Phosphorus at the of 90 kg P_2O_5 and 10 kg S ha^{-1} gave the second highest yield which was statistically similar to 60 kg P_2O_5 and 20 kg S ha^{-1}. Lower stover yield came from control treatment.

Table 2. Effect of Sulphur on the plant, yield and yield contributing characters of SAU Sarisha 1

Level of Sulphur (kg ha^{-1})	Plant height (cm)	Branches $plant^{-1}$	Siliquae $plant^{-1}$ (no.)	Siliqua length (cm)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
0	98.57	3.42	100.60	5.77	2.87	3.80	24.67
10	102.3	4.02	138.3	6.15	3.29	4.57	27.32
20	105.10	4.47	165.7	6.23	3.43	4.58	27.57
30	104.1	4.24	160.10	6.02	3.05	4.19	26.67
LSD (0.05)	10.81	0.30	11.81	1.67	0.86	0.71	0.48
CV (%)	6.33	4.52	5.02	16.61	16.32	9.98	3.01

4.9 Biological yield (t ha^{-1}):

4.9.1 Effect of phosphorus

Different levels of phosphorus exerted significant effect on biological yield (Table 1). Highest biological yield (4.61t ha^{-1}) was obtained from the rate of 60 kg P_2O_5 ha^{-1} which was statistically similar to 30 and 90 kg P_2O_5 ha^{-1} and the control treatment showed the lowest biological yield (3.68 t ha^{-1}).

4.9.2 Effect of sulphur

Biological yield was significantly influenced by sulphur level (Table 2). Sulphur at the rate of 20 kg ha^{-1} produced maximum biological yield (4.58 t ha^{-1}) which was statistically similar to 10 kg S ha^{-1} but the control treatment produced the lowest biological yield (3.80 t ha^{-1}).

4.9.3 Interaction effect of phosphorus and sulphur

Combination of phosphorous and sulphur had significant effect on biological yield. The interaction treatment of 60 kg P_2O_5 and 20 kg S ha^{-1} produced the highest biological yield (6.00 t ha^{-1}) which was statistically similar to 60 kg P_2O_5 and 10 kg S ha^{-1} and 90 kg P_2O_5 with 10 kg S ha^{-1}, and in control the yield was the lowest one.

4.10 Harvest index (HI):

4.10.1 Effect of phosphorus

Harvest index was influenced by different levels of phosphorus. Highest harvest index (27.93%) was obtained from the rate of 60 kg P_2O_5 ha^{-1} which was statistically different from all other treatments. But the lowest (24.56%) was obtained from control which was statistically similar with 0 kg P_2O_5 ha^{-1} (Table 1).

4.10.2 Effect of sulphur

Different rates of sulphur significantly influenced the harvest index (Table 2). At the rate of 20 kg S ha^{-1} showed the highest harvest index (27.57%) and the lowest was produced by the control treatment (24.67%). But sulphur at 10 and 30 kg ha^{-1} responded differently to produce the harvest index. The result was in accordance with that of Chaudhury *et al*. (1991).

Table 3. Interaction effect of phosphorus and sulphur on the plant, yield and yield contributing characters of SAU Sarisha 1

Interaction	Plant height (cm)	Branches plant^{-1}	Siliquae plant^{-1} (no.)	Siliqua length (cm)	Seeds siliqua^{-1} (no.)	1000-seed weight (g)	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
P_0S_0	92.46	3.03	85.10	5.69	9.65	2.42	2.66	3.51	23.93
P_0S_1	96.38	3.09	85.63	5.83	10.53	2.51	2.72	3.63	25.34
P_0S_2	97.62	3.16	89.93	5.84	13.09	2.28	2.83	3.80	25.53
P_0S_3	98.69	3.29	108.60	5.40	10.68	2.60	2.92	3.81	23.36
P_1S_0	102.2	3.14	106.8	5.74	14.65	2.73	3.12	4.04	22.76
P_1S_1	107.0	5.40	198.6	6.90	18.57	3.43	3.23	4.32	29.62
P_1S_2	105.5	3.69	180.4	5.93	19.30	2.90	3.35	4.66	28.23
P_1S_3	103.2	3.75	169.7	5.99	16.53	2.93	3.20	4.50	28.89
P_2S_0	99.08	3.96	98.76	5.85	13.11	2.95	2.81	3.77	25.20
P_2S_1	105.2	3.71	155.2	6.00	18.23	3.10	3.46	4.88	29.10
P_2S_2	111.0	6.93	242.3	7.05	21.61	3.61	4.21	6.00	29.83
P_2S_3	105.2	4.81	181.9	6.35	17.43	2.98	3.10	4.32	28.24
P_3S_0	99.60	3.57	111.9	5.82	13.43	2.67	2.90	3.90	25.64
P_3S_1	100.7	3.91	113.8	5.88	16.18	3.10	3.77	5.13	26.31
P_3S_2	106.2	4.11	150.3	6.10	18.22	3.15	3.51	4.73	25.80
P_3S_3	109.3	5.29	180.3	6.35	18.56	3.39	2.98	4.16	28.37
LSD (0.05%)	10.81	0.30	11.81	1.67	3.08	0.51	0.86	0.71	0.48
CV (%)	6.33	4.52	5.02	16.61	11.86	10.48	16.32	9.98	3.01

P_0 =0 (kg ha^{-1}), P_1=30 (kg ha^{-1}), P_2=60 (kg ha^{-1}), P_3= 90 (kg ha^{-1})

S_0=0 (kg ha^{-1}), S_1=10 (kg ha^{-1}), S_2=20 (kg ha^{-1}), S_3=30 (kg ha^{-1})

4.10.3 Interaction effect of phosphorus and sulphur

Phosphorus and sulphur interaction had significant effect on harvest index (Table 3). The interaction treatment of 60 kg P_2O_5 and 20 kg S ha^{-1} produced the highest harvest index which was statistically different to the other treatments.

From the above discussion it was evident that application of phosphorous and sulphur substantially increased the yield of rapeseed (SAU sarisha 1) was obtained when 60 kg $P_2O_5$and 20 kg S ha^{-1} was applied. Also other yield components of rapeseed showed significant performance in these levels of phosphorus and sulphur.

Chapter V
Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the field of Sher-e- Bangla Agricultural University, Sher-e-bangla Nagar, Dhaka during the period from 17 November 2006 to 3 March 2007 to study the effect of phosphorus and sulphur on the yield and yield components of rapeseed cultivar SAU sarisha 1. The experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with three replications. The rates of phosphorus were 0, 30, 60 and 90 kg P_2O_5 ha^{-1} and those of sulphur were 0, 10, 20 and 30 kg S ha^{-1}. The unit plot size was 6 m^2 (3.0 m X 2.0 m). There were 16 treatment combinations of phosphorus and sulphur in the experiment. The individual and interactive effect of phosphorus and sulphur on yield and yield components of the variety were studied.

Phosphorus at the rate of 60 kg P_2O_5 ha^{-1} gave significantly the tallest plant. Similarly, the highest number of siliquae plant $^{-1}$, seeds $siliqua^{-1}$, highest 1000-seed weight, seed yield, stover yield, biological yield and harvest index were produced by the same rate of phosphorus, and the control treatment showed the poorest performances for yield and yield components. In case of plant height, siliqua length there was no significant effect of different phosphorus levels.

The tallest plant was recorded when sulphur was applied at the rate of 20 kg ha^{-1}. Similarly, the highest number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$, highest 1000-seed weight, seed yield, biological yield and harvest index were obtained from the same treatment, and the control treatment showed the lowest performance. Sulphur had no significant effect on siliqua length, stover yield and branches $plant^{-1}$.

Phosphorus in combination with sulphur showed significant effect on number of branches plant^{-1} siliquae plant^{-1}, seed yield, stover yield, biological yield and harvest index. Interaction effect of phosphorus at the rate of 60 kg and sulphur at the rate of 20 kg ha^{-1} showed highest plant height, seed yield, stover yield, biological yield and harvest index. But in each case, the control interaction treatment of phosphorus and sulphur showed the lowest performance. Phosphorus in combination with sulphur failed to show any significant effect on plant height, siliqua length, seeds siliqua^{-1} and 1000-seed weight. Phosphorus at the rate of 90 kg and sulphur at the rate of 20 kg ha^{-1} gave the highest siliquae plant^{-1}, but the lowest number of siliqua plant^{-1} resulted from the control treatment.

Finally it might be concluded by a close look at the backdrops that both phosphorus and sulphur had significant role in increasing seed yield and yield components of rapeseed. Phosphorus at the rate of 60 kg P_2O_5 and sulphur at the rate of 20 kg S ha^{-1} might be recommended for SAU Sarisa1 for higher seed yield. But for confirmation further research needed to be conducted.

Chapter VI

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CHAPTER VI
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APPENDICES

Appendix i: Physical and chemical characteristics of initial soil at zero (0) to fifteen (15) cm depth

A. Physical composition of the soil

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

B. Chemical composition of soil

Sl.	Soil characters	Analytical data
1	Organic carbon (%)	0.85
2	Total N (kg ha^{-1})	1805
3	Total S (ppm)	222.00
4	Total P (ppm)	845.00
5	Available N (kg ha^{-1})	56.00
6	Available P (kg ha^{-1})	70.00
7	Exchangeable K (kg ha^{-1})	89.00
8	Available S (ppm)	15.50
9	pH (1:2.5 soil to water)	5.55
10	CEC	11.50
11	C:N ratio	8:1

Appendix ii: Monthly average of temperature, Relative humidity, Total rainfall and sunshine hour of the experimental site during the period from 17 November 2006 to February 2007

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
2006	November	30.0	18.0	24.0	71.0	0.0	236.5
	December	26.5	16.0	21.0	72.0	0.0	210.8
2007	January	24.0	14.0	19.5	70.5	4.5	189.5
	February	29.0	18.2	22.5	63.0	3.5	220.5

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