EFFECT OF NITROGEN AND PHOSPHORUS ON THE YIELD, YIELD CONTRIBUTING CHARECTERS AND SEED QUALITY OF RAPESEED (*Brassica campestris*) CV. SAU Sarisha-1

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of nitrogen and phosphorus on the yield, yield contributing characters and seed quality of rapeseed** (*Brassica campestris*) cv. SAU Sarisha-1" 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,** embodies the result of a piece of *bona fide* research work carried out by Mohammad Kamrul Hasan, Registration No. 25151/00293 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.

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EFFECT OF NITROGEN AND PHOSPHORUS ON THE YIELD, YIELD CONTRIBUTING CHARACTERS AND SEED QUALITY OF RAPESEED *(Brassica campestris)* CV. SAU SARISHA-I

ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207 during the Rabi season (October to February) of 2005-2006 to study the effect of different levels of nitrogen and phosphorus on the yield, yield contributing characters and seed quality of newly developed rapeseed *(Brassica campestris)* line SAU-C-F_7. The experiment comprised of four levels of nitrogen viz. 0, 60, 120 and 180 kg N ha^{-1} and four levels of phosphorus viz. 0, 60, 90 and 120 kg P_2O_5 ha^{-1}. The experiment was laid out in a randomized complete block design (factorial) with three replications.

Nitrogen showed significant effect on yield, yield components and oil yield of rapeseed except the number of plant m^{-2}, number of branches $plant^{-1}$, and oil content. Application of nitrogen @ 120 kg ha^{-1} produced the highest plant height, siliquae $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000-seed weight, seed yield, stover yield, biological yield, harvest index and oil yield.

Phosphorus had significant effect on yield, yield attributes and oil yield of rapeseed except number of plant m^{-2} and branches $plant^{-1}$. Application of phosphorus @ 90 kg P_2O_5 ha^{-1} gave the highest plant height, siliquae $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000-seed weight, seed yield, stover yield, biological yield, harvest index, oil content and oil yield.

Combined effect of nitrogen along with phosphorus showed significant effect on all the parameter of rapeseed except number of plant m^{-2} and branches $plant^{-1}$. The combination of 120 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1} produced highest plant height, siliquae $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$, 1000-seed weight, seed yield, stover yield, biological yield, harvest index, oil content and oil yield. From the above findings it is noted that application of 120 kg N & 90 kg P_2O_5/ha could be optimum dose for increasing seed & oil yield of rapeseed cv. SAU Sarisha-1.

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ACRONYMS

%	=	Percent
°C	=	Degree Celsius
AEZ	=	Agro- Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CEC	=	Cation Exchange Capacity
cm	=	Centi-meter
CV %	=	Percentage of Coefficient of Variance
cv.	=	Cultivar (s)
DAS	=	Days After Sowing
et al.	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	gram (s)
HI	=	Harvest Index
hr	=	hour (s)
K_2O	=	Potassium Oxide
kg	=	kilogram (s)
kg/ha	=	kilogram per hectare
L_n	=	Natural Logarithum
LYV	=	Low yielding variety
m^2	=	meter square
mm	=	millimeter
N	=	Nitrogen
No	=	Number
NS	=	Non significant
P	=	Phosphorus
P_2O_5	=	Phosphorus Penta Oxide
PK	=	Phosphorus, Potassium
ppm	=	Parts per million
RDA	=	Recommended Dietary Allowance
SA	=	Surface area
SAU	=	Sher-e- Bangla Agricultural University
var.	=	Variety

Chapter 1

INTRODUCTION

Rapeseed (*Brassica campestris* L) is an important oil seed crop belongs to the family Cruciferae. Rapeseed along with mustard is currently ranked as the world's third most important oil crop in terms of area and production (FAO, 1999) but it occupies the first position in respect of area and production among the oils crop grown in Bangladesh (BBS, 1999). The seeds of mustard and rapeseed contain 42% oil and 25% protein (Khaleque, 1985).

Oil seed crops play a vital role in human diet. It is not only rich source of energy (about 9 k cal/g) but also rich in soluble vitamins A, D, E and K. The National Nutrition Council (NNC) of Bangladesh reported that recommended dietary allowance (RDA) per capita per day should be 6g of oil for a diet with 2700 Kcal. On RDA basis, the edible oil need for 150 millions people are 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984). In 2004-2005 Bangladesh produced only 0.41 million tons of oilseed (BBS, 2005).

Rapeseed-mustard is the principal oilseed crop of Bangladesh. In Bangladesh, it covers an area of 0.28 million hectare with production of 0.21 million tons (BBS, 2005). Rapeseed oil is widely used as cooking oil and medicine. Rapeseed oil cake is used as feed for cattle and fish and manure for crops. Domestic production of edible oil almost entirely comes from rape and mustard occupying only about 2% of total cropped area in Bangladesh (BBS, 2002). The annual oil seed production of 0.41 million tons in which the share of rapeseed mustard was 0.21 million tons, which comes about 52% of the total edible oilseed production (BBS, 2005). Among the oilseed cropped area 74% is covered by mustard and rapeseed, 17% by sesame and 9% by groundnut (BBS, 1999). The average yield of rapeseed in Bangladesh is very low (0.77 t/ha) that is less than 50% of the world average (FAO, 2004). The major rape and mustard growing areas of Bangladesh shown in Appendix I.

Bangladesh is running with acute shortage of about 70% edible oil. Annually producing about 0.16 million tons of edible oil as against the requirement of 0.5 million tons and to meet up the demand, the country has to import oil and oilseeds to the tune of about 160 million US$ every year (Wahhab *et al.*, 2002).

The shortage of edible oil has become a chronic problem for the nation. To fulfil the requirement, the country has to import edible oils at the cost of huge amount of foreign exchange. Therefore, the country has to increase its production to satisfy its internal demand. The cultivation of rapeseed has to compete with other food grain crops. Due to this reason, oilseed crops have been shifted to marginal land.

Rapeseed productivity is very low due to poor fertilization, traditional cultivation practices, local varieties and scarcity of HYV seed etc. The yield of rapeseed can be augmented with the use of high yielding varieties and appropriate agronomic management. Fertilizer is the dependending source of nutrient that can be used to boost up growth and yield of mustard (Sinha *et al.*, 2003, Shukla *et al.*, 2002a, Meena *etal.*, 2002 and Zhao *et al.*, 1997). High yielding varieties of rapeseed are very responsive to fertilizers espicially nitrogen (Gupta *et al.*, 1972; Ali and Rahman, 1986; Sharawat *et al.*, 2002 and Patel *etal.*, 2004).

Proper fertilizer management plays a key role to get higher yield and nitrogen is an essential nutrient required for obtaining good yield. Rapeseed is highly sensitive to nitrogen and this element has tremendous influence on plant height, dry matter accumulation and the yield attributes (Srinivas and Raju, 1997; Saikia *et al.*, 2002; Singh *et al.*, 2002; Shukla *et al.*, 2002b and Tripathi and Tripathi, 2003). Excessive use of this element may produce too much of vegetative growth and thus fruit production may be impaired (Sheppard and Bates, 1980). Overseas studies have demonstrated that the adequate nitrogen nutrition is essential for yielding in rapeseed (Krogman and Hobbs, 1975; Singh and Yosuf, 1979).

Mustard is highly sensitive to phosphorus and this element has tremendous influence on growth, yield and oil content of mustard. The literature shows that phosphorous has significant effect on plant height, siliqua per plant and other growth factors and yield of mustard (Patel and Shelke, 1999; Arthamwar *et al.*, 1996).

Proper dose in fertilization is an essential factor to maximize rapeseed production in Bangladesh soil. Although N and P fertilizer play a vital role in enhancing the production of rapeseed and thereby reducing the oil deficit in the country. Not yet any studies have been done in this respect with the new variety. Taking the above mentioned points in combination , the present study was under taken with following objectives:

1) To find out the optimum nitrogen level for the yield and quality of rapeseed cv. SAU Sarisha-1.
2) To find out the optimum phosphorous level for the yield and quality of rapeseed cv. SAU Sarisha-1.
3) To find out combined effect of nitrogen and phosphorous is relation to yield, yield contributing characters and oil content of rapeseed cv. SAU Sarisha-1.

Chapter 2

REVIEW OF LITERATURE

Among the oilseed crops, rapeseed and mustard occupies topmost position in Bangladesh. Sher-e-Bangla Agricultural University has already developed new variety name (SAU Sarisha-1) which belongs to the group of rapeseed. The proper fertilizer management accelerates its growth and influences its yield as well as oil content. The literature on the work done pertaining to the effect of nitrogen and phosphorus nutrients on the yield and yield attributes of the crops belonging to the group rapeseed and mustard have been cited here. Therefore, available findings of the direct effect of nitrogen and Phosphorus and combined effect relevant to the present study have also been briefly reviewed under the following heads.

2.1 Effect of nitrogen

2.1.1 Plant height

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30, and 60 kg N/ha under irrigated or non-irrigated conditions in a field experiment. They observed that plant height increased with increasing rate of nitrogen and was higher under irrigated than non-irrigated conditions. Singh *et al.* (2002) also reported that plant height increased significantly with successive increase in nitrogen up to 120 kg/ha.

BARI (1999) performed trial in two different regions of Bangladesh, at Joydebpur & Ishwardi to find out the effect of N on the yield of mustard. The experiment was conducted with 3 levels of nitrogen 0, 120, 160 kg/ha and plant height was found 87.78, 113.94, 106.46 cm, respectively at Joydebpur and 90.79, 118.46, 113.69 cm at Ishwardi. The highest plant height was found in both the location at 120 Kg N/ha.

Islam and Mondal (1997) showed that the maximum plant height was obtained 93.6 cm at 300 kg N/ha while applying different levels of nitrogen i.e. 0, 100, 200, 300 kg/ha.

Ali and Ullah (1995) reported maximum plant height with 120 kg N/ha when different doses of nitrogen 0, 40, 90, 120 kg/ha were given to the plant.

Singh and Saran (1989) conducted an experiment with *Brassica campestris* var. Toria and with different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased plant height.

Mondal and Gaffar (1983) observed highest plant height of the variety 'Sampad' following treatment 140 kg N/ha, which was identical with 105 kg N/ha.

Bhan and Singh (1976) reported that *Brassica juncea* was found taller plant height with 120 kg N/ha.

2.1.2 Number of branches per plant

Tripathi and Tripathi (2003) conducted an experiment to investigate the effect of N levels (80, 120, 160 and 200 kg/ha) on the branches number of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits i.e., at sowing, first irrigation and 60 days after sowing. Results showed that the number of primary branches per plant increased up to 200 kg N/ha.

Sharma and Jain (2002) carried out an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) in a cropping system and observed that 80 kg N/ha resulted the highest number of branches (24.4) per plant.

Singh *et al.* (2002) reported that primary and secondary branches per plant increased significantly with successive increase in nitrogen rate up to 120 kg/ha.

Shukla *et al.* (2002b) conducted an experiment to study the effect of nitrogen for Indian mustard (*B. juncea*). They obtained the highest number of branches per plant with 120 kg N/ha.

Tarafder and Mondal (1990) studied the effect of nitrogen on seed yield of mustard (var. Sonali Sarisha) and found that the number of branches per plant increased with increasing levels of nitrogen. The maximum number of primary branches per plant was found with 120 kg N/ha.

2.1.3 Number of siliquae per plant

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed with four levels of nitrogen (0, 80, 160 and 240 kg N/ha). He observed that adequate N fertilization is important in increasing siliqua number per plant and observed highest siliqua number per plant of summer oilseed rape at the rate of 160 kg N/ha.

Sharma and Jain (2002) studied with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) and found that the application of 80 kg N/ha resulted in the highest number of siliquae per plant (260.9). Singh *et al.* (2002) also reported that siliquae per plant increased significantly with successive increase in nitrogen up to 120 kg/ha.

Shukla *et al.* (2002b) conducted an experiment to observe the effect of nitrogen for Indian mustard (*B. juncea*). They found that maximum number of siliquae per plant was obtained with the application of 120 kg N/ha.

Abadi *et al.* (2001) indicated that N had significant effect to increase the number of siliquae per plant of rapeseed up to 120 kg N/ha.

BARI (1999) reported 22.7, 42.0, 45.6 and 48.0 siliquae per plant of mustard with 0, 80, 120 and 140 N kg/ha respectively.

Jensen (1990) observed 1974.0, 2936.6, 3315.1 and 5023.8 siliquae per plant in with 0, 50, 100 and 200 kg N/ha, respectively.

Singh and Saran (1989) conducted an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased the number of siliquae per plant.

2.1.4 Length of siliqua

Shukla *et al.* (2002b) conducted an experiment to study the effect of nitrogen for Indian mustard (*B. juncea*). They observed maximum siliqua length with the application of 120 kg N/ha. Singh *et al.* (2002) also reported that growth characters and length of siliqua increased significantly with successive increase in nitrogen up to 120 kg/ha.

2.1.5 Number of seeds per siliqua

Shukla *et al.* (2002b) conducted an experiment to study the effect of nitrogen for Indian mustard (*B. juncea*). They obtained maximum number of seeds per siliqua when nitrogen was applied at 120 kg/ha.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) and observed that the application of 80 kg N/ha resulted in the highest number seeds (15.3) per siliqua.

2.1.6 Weight of 1000-seed

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of four levels of nitrogen (0, 80, 160 and 240 kg N/ha). He observed that adequate N fertilization is important in increasing 1000- seed weight in summer oilseed rape and suggested that the rate of 160 kg N/ha will be adequate for the crop to meet its N requirements. 1000-seed weight differs with nitrogen levels that enhanced yield.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) and found that the application of 80 kg N/ha increased 1000-seed weight (3.55 g).

Shukla *et al.* (2002b) conducted an experiment to study the effect of nitrogen for Indian mustard (*B. juncea*). They obtained maximum 1000-seed weight with the application of 120 kg N/ha.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased 1000-seed weight.

2.1.7 Seed yield

Sinsinwar *et al.* (2004) reported an that the increase in seed yield of Indian mustard with each increment of N fertilizer up to 60 kg/ha. On an average, the increase in seed yield compared to the control was 33.3 and 83.8% with 30 and 60 kg N/ha, respectively.

Singh (2004) performed a field experiment using blue green algae (BGA) and *Azolla* in integration with graded levels of N fertilizer in rice followed by rapeseed. The highest yield was recorded with higher dose of N (80 kg N/ha) in integration with *Azolla*.

Tripathi and Tripathi (2003) conducted an experiment to investigate the effect of N levels (80, 120, 160 and 200 kg/ha) on the yield of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits i.e., at sowing, first irrigation and 60 days after sowing. Results showed that seed yield increased with increasing N levels up to 160 kg N/ha.

Singh and Prasad (2003) reported that 120 kg N/ha gave the highest seed yield (20.24 q/ha). But the highest cost benefit ratio (0.85) was obtained with 180 kg N/ha.

Kumar and Singh (2003) conducted an experiment during rabi season with different levels of nitrogen for Indian Mustard (*Brassica juncea*). They reported that the maximum seed yield (24.51 q/ha) was observed with 150 kg N/ha.

Ozer (2003) studied the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N/ha) on two cultivars of rapeseed. He observed that adequate N fertilization is important in yield formation in summer oilseed rape and suggested that the rate of 160 kg N/ha will be about adequate for the crop to meet its N requirements.

Shukla *et al.* (2002b) conducted an experiment to study the effect of nitrogen for Indian mustard (*B. juncea*). They observed maximum seed yield per hectare with the application of 120 kg N/ha.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) and found that the application of 80 kg N/ha resulted in the highest seed yield (1649.22 kg/ha). The highest values of seed yield and yield attributes were recorded for *S. canabina*–Indian mustard receiving 80 kg N/ha.

Sidlauskas (2000) observed that the yield of rapeseed was increased with the increasing rate of nitrogen levels up to 120 kg/ha. Further increase of nitrogen level did not affect the seed yield.

BARI (1999) reported yields of mustard 493.3, 833.3, 940.0 and 993.7 kg/ha showed with four levels of nitrogen (0, 80,120,140 kg/ha) respectively.

Singh *et al.* (1998) reported that seed and oil yields as well oil component values were increased with increasing nitrogen rates (0, 40, and 80 kg N/ha).

Islam and Mondal (1997) in a field trial showed that application of four levels of nitrogen 0, 100, 200, 300 kg/ha yielded 0.69, 1.29, 1.45, 1.21 t/ha seeds, respectively.

Hossain and Gaffer (1997) conducted an experiment with 5 levels of nitrogen viz. 0, 100, 150, 200, 250 kg/ha on rapeseed and maximum yield was found 1.73 t/ha with 250 kg N/ha.

Mondal *et al.* (1996) reported that the highest seed yield of rapeseed (1.40 t/ha) was obtained from fertilizer levels of 150:90:100:30:4:1 kg/ha of N, P_2O5, K_2O, S, Zn and B along with 6 tones cowdung.

Tuteja *et al.* (1996) investigated the effect of nitrogen at 60, 90 and 120 kg/ha on the yield of *Brassica juncea* cv. Varuna. Seed yield was highest (1.12 t/ha) with 120 kg N/ha.

Perniona *et al.* (1989) studied the effect of nitrogen (50, 100 and 150 kg/ha) on winter rape and found that average seed yield increased with the increased rate of nitrogen at 150 kg/ha.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg/ha increased the seed yield. This dose gave seed yields of 1.20 t/ha compared to 0.89 t/ha without nitrogen. A further increase in yield with 90 kg/ha was not significant.

Mondal and Gaffer (1983) conducted experiment with Sampad variety of mustard having 5 levels of N (0, 35, 70, 105 and 140 kg/ha) and found the highest seed yield (1280.95 kg/ha) from N treatment of 140 kg/ha, which was found identical with that of 105 kg/ha.

2.1.8 Stover yield

Prasad *et al.* (2003) reported the effect of N, S and Zn fertilizers on the nutrient uptake, quality and yield of Indian mustard cv. Vaibhav. The treatments consisted of 60 kg N/ha singly or in combination with 30 kg P, 20 kg S, 5 kg Zn; 30 kg P + 20 kg S; 30 kg P + 5 kg Zn; 20 kg S + 5 kg Zn; or 30 kg P + 20 kg S + 5 kg Zn/ha. N, P, S and Zn were applied through urea, diammonium phosphate, gypsum and zinc oxide, respectively. The application of 60 kg N + 30 kg P + 20 kg S + 5 kg Zn gave the highest stover yield (33.08 q/ha).

Singh and Prasad (2003) also mentioned that 120 kg N/ha gave the highest stover yield (12.22 q/ha)

2.1.9 Harvest index

Shukla and Kumar (1997) grew six varieties of Indian mustard to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content. They found that N application at the rate of 120 kg/ha significantly influenced harvest index.

2.1.10 Oil content

Singh and Meena (2003) conducted a field experiment to determine the effect of N fertilizers (20, 40, 60, 80 and 100 kg N/ha) on the oil and protein yield of Indian mustard cv. Varuna. Results showed that 40 kg N/ha gave the highest oil content (39.61%).

Meena and Sumeriya (2003) carried out a study to evaluate the effect of nitrogen (0, 30, 60 and 90 kg/ha) on oil content of mustard *Brassica juncea*. Application of 60 kg N/ha gave the maximum oil content (37.04%) compared to no nitrogen application. Abadi *et al.* (2001) also indicated that N had a significant effect on oil content of rapeseed and mustard.

Shukla and Kumar (1997) investigated six varieties of Indian mustard (Krishna, Varuna, Vardan, Kranti, Rohini and Pusa Bold) to assess the effect of nitrogen fertilization on seed yield and oil content. A decreasing trend of oil content was observed with the increase in N fertilization.

2.1.11 Oil yield

Ali *et al*. (1996) found that application of 120 kg N/ha favourably influenced the oil yield of rapeseed.

Gawai *et al*. (1994) performed an experiment to assess the impact of 0-100 kg N/ha on the performance of mustard (*Brassica juncea*) cv. TM-17 and concluded that oil yield increased with N rate, reaching a plateau at 75 kg/ha.

2.2 Effect of phosphorus

2.2.1 Plant height

Birbal *et al*. (2004) conducted an experiment in India during the 1996/97 and 1997/98 rabi season with 4 levels of phosphorus viz. 0, 25, 80 and 75 kg/ha. The maximum plant height was observed with 75 kg p/ha.

Chaubey *et al*. (2001) performed an experiment during the rabi season to evaluate the response of mustard (*Brassica juncea*) with 3 levels of phosphorus. They observed that plant height increased significantly with the increasing of P_2O_5 up to 60 kg/ha.

Ram *et al*. (1999) reported that application of 15 kg P_2O_5/ha significantly increased the plant height.

2.2.2 Number of branches per plant

Chaubey *et al.* (2001) performed and experiment during the rabi season in India with 3 levels of phosphorus viz. 0, 40 and 60 kg/ha. They reported that number of branches per plant increasing with the increasing level of phosphorus up to 60kg P_2O_5/ha.

Birbal *et al.* (2004) carried out an experiment in India during 1996/97 and 1997/99 rabi seasons with 4 levels of phosphorus viz. 0, 25, 50 and 75 kg P/ha. They observed increased number of branches with increasing level of phophorous and found maximum number of branches per plant at 75 kg P/ha.

Davaria *et al.* (2001) conducted an experiment in India during 1994/95 rabi season with 3 levels of P_2O_5 viz. 0, 25 and 50 kg/ha. They observed that number of primary branches per plant (6.9) and secondary branches per plant (12.6) were highest at 50 kg P_2O_5/ha.

2.2.3 Number of siliquae per plant

Sumeria (2003) reported that P has a great influence on the yield attributes of mustard (*Brassica juncea*). He conducted an experiment during rabi season in India with 3 levels of phosphorus viz, 20, 40 and 60 kg/ha. He observed that application of 60 kg P/ha significantly increased the number of siliquae per plant.

Kantwa and Meena (2002) conducted an experiment in Indian for mustard *(Brassica juncea)* with different levels of phophorus viz. 15, 30 and 45 kg/ha. They reported that application of phosphorus upto 45 kg/ha significantly increased the number of siliquae per plant.

Singh (2002) conducted an experiment during 1998/99 and 1999/2000 to findout relationship between the phosphorus and yield attributes of Indian mustard (*Brassica juncea*) with 5 levels of phosphorus viz. 1, 15, 30, 45 and 60 kg/ha. The maximum siliquae number per plant was observed with 45kg p/ha.

2.2.4 Length of siliqua

Chaubey *et al.* (2001) performed an experiment during the rabi season in India with 3 levels of phophorous viz. 0, 30, 60 kg/ha. The highest siliqua length was observed with 60 kg P_2O_5/ha.

Ram *et al.* (1999) conducted an experiment in India and reported that application of phosphorous influenced the length of siliqua. The maximum length of siliqua was observed with 15 kg P_2O_5/ha over the control.

Verma *et al.* (2002) studied the response of Indian mustard to 20, 45 and 60 kg P_2O_5/ha and observed significant influence of phosphorus to increase length of siliqua only upto 45 kg P_2O_5/ha.

2.2.5 Seeds per siliqua

Birbal *et al.* (2004) reported that phosphorus has a great influence on seeds of mustard (*Brassica juncea*). They conducted an experiment during rabi season in Indian with 4 levels of phosphorus viz. 0, 25, 50, and 75 kg/ha. The maximum seeds per siliqua was found with 75 kg P/ha.

Davaria *et al.* (2001) revealed an experiment during the 1994/95 rabi season with 3 levels of phosphorus viz. 0, 25 and 50 kg/ha. They found that phosphorus application with 50 kg P_2O_5/ha gave the highest seeds per siliqua (12.1).

Chaubey *et al.* (2001) conducted an experiment in India with mustard (*Brassica juncea*) with different levels (0, 40, and 60 kg P_2O_5/ha) of phosphorus. The maximum seeds per siliqua was found with 60 kg P_2O_5/ha.

Sumeria (2003) conducted an experiment in India with 3 levels of phosphorus viz. 20, 40 and 60 kg/ha. The reported that 60 kg P/ha gave the highest seeds per siliqua among the treatments.

2.2.6 1000-seed weight

Sumeria (2003) reported that phosphorus has a great influence on the seed weight of mustard (*Brassica juncea*). He conducted an experiment with 3 levels of phosphorus viz 20, 40 and 60 kg/ha. The maximum 1000-seed weight was observed with 60 kg P/ha.

Birbal *et al.* (2004) reported that seed weight of mustard greatly affected by phosphorous. Maximum 1000-seeds weight (3.54 g) was found with 75kg P/ha.

Kantwa and Meena (2002) performed an experiment in India during the rabi season with 3 levels of phosphorus viz. 15, 30 and 45 kg/ha. They reported that 30 kg P_2O_5/ha significantly increased 1000-seeds weight of mustard.

Davaria *et al.* (2001) carried out an experiment during rabi season to determine the effect phosphorus on the yield and yield attributes of mustard cv. Gujrat Mustard-1 with 3 levels of phosphorus viz. 0, 25 and 50 kg/ha. The maximum thousand seeds weight was found with 50 kg P/ha.

2.2.7 Seed yield

Davaria *et al.* (2001) reported that phosphorus has a great influence on the yield of mustard (*Brassica juncea*). They conducted an experiment in India during 1994/95 rabi season with 3 levels of P_2O_5 viz. 0, 25 and 50 kg/ha. The maximum seed yield (1.54 t ha $^{-1}$) was observed with 50 kg P_2O_5/ha.

Arthamwar *et al.* (1996) reported that every increase in the level of phosphorus (0, 40 and 80kg P_2O_5/ha) significantly improved the seed yield of Indian mustard.

Birbal *et al.* (2004) performed an experiment of India during 1996/97 and 1997/98 rabi seasons with 4 levels of phosphorus viz. 0, 25, 50, 75 kg/ha. They observed that phosphorus at 75 kg/ha gave the maximum seed yield.

Chaubey *et al.* (2001) conducted an experiment during rabi season with 3 levels of P_2O_5 viz. 0, 40, 60 kg/ha. They reported that phosphorus application increased significantly seed yield of mustard (*Brassical juncea*) and the maximum seed yield was observed with 60 kg P_2O_5/ha.

Singh (2002) conducted an experiment during 1998/99 and 1999/2000 rabi seasons with 5 levels of P viz. 1, 15, 30, 45 and 60 kg/ha. He reported that phosphorus has a great influence on the yield of mustard (*Brassica juncea*) and the maximum seed yield (1.14 and 1.38 t ha^{-1} in 1999 and 2000) was recorded from application of 45 kg P/ha.

Sumeria (2003) conducted an experiment in India during rabi season with 3 levels of phosphorus viz. 0, 20, 40 and 60 kg/ha. The maximum seed yield (1.40 t ha^{-1}) was observed at 60 kg P/ha.

Kantwa and Meena (2002) conducted an experiment in India during 1999/2000 rabi season with 3 levels of phophorus viz. 15, 30 and 45 kg/ha. They found that the application of phophorus upto 45 kg/ha significantly increased the seed yield of mustard.

2.2.8 Stover yield

Patel and Shelke (1998) showed that stover yield of Indian mustard increased significantly with application of phosphorus. They observed that 80 kg P_2O_5/ha gave the maximum stover yield.

Birbal *et al.* (2004) conducted an experiment in India during 1996/97 and 1997/98 winter season with 4 levels of phosphorus Viz. 0, 25, 50, 75 kg/ha. The maximum stover yield was observed with 75 kg P/ha.

Davaria *et al.* (2001) conducted an experiment in India during the 1994/95 rabi season with 3 levels of P_2O_5 viz. 0, 25, 50 kg/ha. The maximum stover yield (39.44 t/ha) was observed with 50 kg P_2O_5/ha.

Sumeria (2003) performed an experiment during the rabi season in India with 3 levels of phosphorus viz. 20, 40, 60 kg/ha. He found that 60kg P/ha gave the highest stover yield.

Kantwa and Meena (2002) conducted a study to evaluate the effect of phosphorus on the stover yield of Indian mustard. They observed that P_2O_5 upto 45 kg/ha significantly increased stover yield.

2.2.9 Biological yield

Sharma and Singh (2003) conducted an experiment during 1998/99 and 1999/2000 rabi seasons with different weed management and phosphorous levels (0, 8.8, 17.6 and 26.4 kg/ha through diammonium phosphate) to study the yield and yield quality of Indian mustard. They found application of phosphorous at 17.6 kg/ha along with weed management significantly increase of biological yield.

2.2.10 Oil content

Sharma and Singh (2003) conducted an experiment during 1998/99 and 1999/2000 rabi seasons with different weed management and phosphorous levels (0, 8.8, 17.6 and 26.4 kg/ha through diammonium phosphate) to study the yield and yield quality of Indian mustard. They found application of phosphorous at 17.6 kg/ha along with weed management gave the highest oil content.

Arthamwar *et al.* (1996) reported that every increase in the level of phosphorous from 0 to 80 kg/ha significantly improved oil content of Indian mustard.

2.2.11 Oil yield

Poonia *et al.* (2002) conducted an experiment with three levels of phosphorous (20, 40 and 60 kg P_2O_5/ha) result showed that application of phosphorous at 40 kg/ha significantly increased the oil yield of Indian mustard.

Arthamwar *et al.* (1996) reported that every increase in the level of phosphorous from 0 to 80 kg P_2O_5/ha significantly improved oil yield of Indian mustard.

2.3 Combined effects of nitrogen and phosphorous

2.3.1 Plant height

Shamsuddin *et al.* (1987) conducted an experiment with five levels of nitrogen Viz 0, 30, 60, 90 and 120 kg N/ha and four levels of irrigation (30, 45, 60, 75 DAS) and observed that plant height of mustard increased progressively with increasing levels of nitrogen but was not significantly differed with the application of different levels of nitrogen. Nitrogen at the rate of 120 kg/ha along with two irrigation (at 30 DAS and 60 DAS) gave the highest plant height.

2.3.2 Number of branches per plant

Singh *et al.* (2003) studied the effect of nitrogen rates (60, 120 and 180 kg/ha) and row spacing (30, 45 and 60 cm) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg/ha with 30 cm row spacing produced higher number of branches per plant.

Shamsuddin *et al.* (1987) worked with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation (30, 45, 60, 75 DAS) and observed that nitrogen at the rate of 120 kg/ha along with two irrigation (at 30 DAS and 60 DAS) gave the highest number of primary branches per plant (5.03).

2.3.3 Number of siliquae per plant

Singh *et al.* (2003) conducted an experiment and studied the effect of row spacing (30, 45 and 60 cm) and nitrogen rates (60, 120 and 180 kg/ha) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg/ha with 30 cm row spacing produced higher number of siliquae per plant (48.03), siliqua weight (2.09) compared to those of 60 kg N/ha.

Shamsuddin *et al.* (1987) conducted an experiment with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation (30, 45, 60, 75 DAS) They observed that N at the rate of 120 kg/ha along with two irrigation (at 30 DAS snd 60 DAS) significantly increased the number of siliquae per plant.

Mina (2003) performed an experiment during the rabi season with 4 levels of phosphorus viz. 0, 20, 40 and 60 kg/ha and 4 levels of Zn viz. 0, 2.5, 5 and 7.5 kg/ha. Result Showed that increase the number of siliquae per plant up to 40 kg P/ha and 5 kg Zn/ha.

2.3.4 Length of siliqua

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased the length of siliqua. However, the significant increase in length of siliqua was recorded the application of nitrogen at 120 kg/ha along with phosphorus 45 kg/ha.

2.3.5 Number of seeds per siliqua

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and five levels of P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased the number of seeds per siliqua. The maximum number of seeds per siliqua was found with 120 kg N/ha and 60 kg P/ha.

Tarafder and Mondal (1990) conducted an experiment during rabi season with 4 levels of nitrogen viz 0, 30, 60 and 120 kg/ha. and 3 levels of phosphorus viz. 0, 30 and 60 kg/ha. They found that the combine effect of nitrogen 120 kg/ha and phosphorus 60 kg/ha increased the number of seeds per siliqua.

2.3.6 1000-seed weight

Singh (2002) conducted an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased 1000-seed weight. However, the significant increase in 1000-seed weight was recorded in 120 kg N/ha along with phosphorus 30 kg/ha.

Shamsuddin *et al.* (1987) worked with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation (30, 45, 60, 75 DAS) and observed that 1000-seed weight increased progressively with the successive increase of N rate up to 120 kg/ha with two irrigation (at 30 DAS and 60 DAS).

2.3.7 Seed yield

Singh *et al.* (2003) conducted an experiment for determining the effect of nitrogen rates (60, 120 and 180 kg/ha) and row spacing (30, 45 and 60 cm) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg/ha with 30 cm row spacing produced higher seed yield (2.55 q/ha).

Khan *et al.* (2003) studied the interactive effect of nitrogen (0, 40, 60 and 80 kg/ha) and plant growth regulators (cycocel and ethrel both at 200 or 400 ppm) on the photosynthetic biomass production and partitioning in response of seed yield of Indian mustard cv. Alankar and found that 80 kg/ha with 200 ppm ethrel increased the seed yield.

Singh (2002) performed a study with variety Varuna of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) and P (0, 15, 30, 45 and 60 kg/ha). Application of N and P increased the seed yield. The maximum seed yield (12.98 q/ha) were obtained with the application of nitrogen at 120 kg/ha with 60 kg P/ha.

Shukla *et al.* (2002a) conducted an experiment to investigate the effect of N (60, 90 or 120 kg/ha) and S (0 or 40 kg/ha) on the yield and yield attributes of rape cultivars. Sulphur did not significantly affect the seed yield and yield attributes. But N at 120 kg/ha produced higher seed yield than N at 60 and 90 kg/ha.

Ghosh *et al.* (2001) conducted an experiment to study the response of 3 levels of N (0, 40 and 80 kg/ha), 3 levels of K (0, 12.5 and 25 kg/ha) and biofertilizers

(*Azotibacter, Azospirillum*) under irrigated condition. They observed that maximum yield of rapeseed was obtained following 80 kg N/ha along with 12.5 kg K/ha.

Patel (1998) conducted an experiment and studied the response of mustard (*Brassica juncea*) cv. Varuna to 4 levels of nitrogen (0, 20, 40 and 80 kg/ha) and 3 levels of irrigation (30, 45, 60 DAS). The maximum seed yield was found with 80 kg N/ha with two irrigation.

Shukla and Kumar (1997) grown six varieties of Indian mustard to assess the effect of nitrogen fertilization on yield attributes, seed yield and oil content of the verities. They found that N application at 120 kg/ha significantly influenced the seed yield.

Gurjar and Chauhan (1997) observed that Pusa Bold and Kranti were grown in winter seasons at 5 N + P levels and at row spacing of 30 cm or 45 cm. They found that seed yield did not differ between cultivars, was greater at 30 cm spacing (1.68 vs. 1.12 t/ha) and increased up to 75 kg N + 50 kg P_2O_5/ha.

Arthamwar *et al.* (1996) conducted an experiment with mustard varieties (Pusa Bold and T-59) having 3 levels of N (0, 50 and 100 kg) and P_2O_5 (0, 40 and 80 kg/ha). Result showed that highest seed yield (1.20 t/ha) obtained with N at of 100 kg/ha and 80 kg P_2O_5/ha.

Thakuria and Gogoi (1996) conducted an experiment on *Brassica juncea* cv, TM 2, TM 4 and Varuna to evaluate the effect of two row spacing (30 cm. and 45 cm.) with 4 levels of nitrogen fertilizer (0, 40, 80 and 120 kg N/ha). Seed yield and yield components significantly increased with increasing N application up to 80 kg/ha with 30 cm row spacing.

Tarafder and Mondal (1990) set an experiment to evaluate the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sarisha) and found that seed yield increased with increasing levels of nitrogen and sulphur. The results revealed that the nitrogen at the rate of 120 kg/ha with 30 kg S/ha produce the economic seed yield in mustard in the grey terrace soil of Joydebpur.

Shamsuddin *et al.* (1987) conducted an experiment with five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and four levels of irrigation (30, 45, 60, 75 DAS). They reported that maximum seed yield was found with 120 kg N/ha along with two irrigation (at 30 DAS and 60 DAS).

Mondal and Gaffer (1983) conducted experiment with Sampad variety of mustard having 5 levels of N (0, 35, 70, 105 and 140 kg/ha) and four levels of P_2O_5 (0, 35, 70 and 105 kg/ha). The highest seed yield (1280.95 kg/ha) was obtained from the combination treatment of 140 kg N/ha and 70 kg P_2O_5/ha.

2.3.8 Stover yield

Meena *et al.* (2002) conducted an experiment to study the effect of nitrogen, irrigation and intercultural operation on yield and yield attributes of mustard. The results of experiment revealed that two irrigation with the application of 60 kg N/ha registered significantly higher stover yield of mustard over control.

Singh *et al.* (2002) reported that stover yield increased significantly with successive increase in nitrogen up to 120 kg/ha with two irrigation.

2.3.9 Oil content

Patel *et al.* (2004) set an experiment to investigate the effect of spacing (30 and 40 cm) and N rates (50, 75 and 100 kg/ha) on the growth, yield and quality of Indian mustard cv. GM-2. They reported that oil contents decreased with increasing nitrogen levels. Saha *et al.* (2003) also reported the highest oil content at 30 kg N/ha.

Singh *et al.* (2004) conducted an experiment to study the response of Indian mustard cv. T-59 with different levels of nitrogen and sulfur rates. Different levels of nitrogen (0, 30, 60, 90 and 120 kg/ha) application did not differed the oil content in mustard but application of sulfur 30 kg/ha had significant effect on oil content.

Prasad *et al.* (2003) reported the effects of N, S and Zn fertilizers on nutrient uptake, quality and yield of Indian mustard (cv. Vaibhav) and the application of 60 kg N/ha+30 kg S/ha+5 kg Zn/ha gave the highest oil content (39.98 %).

Dubey *et al.* (1994) carried out an experiment on *B. juncea* cv. Varuna and was given 0, 30, 60 or 90 kg N/ha under irrigated condition. Seed oil content decreased by N application.

Mina *et al.* (2003) revealed an experiment with 4 levels of phosphorous viz. 0. 20, 40 and 60 kg/ha and 4 levels of Zn viz. 0, 2.5, 5.0 and 7.5 kg/ha. The maximum oil content was found with 40 kg P/ha and 5 kg Zn/ha.

Sumeria (2003) conducted a field experiment to evaluate the response of cultivars (Sanjukta, Asceh and Varuna) to plant population levels (222,000, 148,000 and 111,000. ha) and phosphorous levels (20, 40, and 60 kg/ha) on yield, oil and protein content of rainfed Indian mustard. They observed significant increase of oil yield up to 60 kg p/ha.

Mina *et al.* (2003) performed an experiment during rabi season with 4 levels of p (0, 20, 40 and 60 kg/ha) and 4 levels of zinc (0, 2.5, 5.0, 7.5 kg/ha). They observed that the application of phosphorous and zinc increasesed the oil yield following 40 kg P/ha and 5 kg Zn/ha.

Chapter 3

MATERIALS AND METHODS

The experiment was undertaken during rabi season (October to February) of 2005-06 to examine the response to different levels of nitrogen and phosphorus on yield, yield attributes and seed quality of rapeseed cv. SAU Sarisha-1 .

3.1 Experimental site

The experiment was carried out at Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. It is located at $90^0 22'$ E longitude and $23^0 41'$ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological region of "Madhupur Tract" (AEZ 28) of Nodda soil series. The soil was sandy loam in texture having pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix II.

3.2 Climate

Cold temperature and minimum rainfall is the main feature of the rabi season. The monthly total rainfall, average sunshine hour, temperature during the study period (October to February) are shown in Appendix III.

3.3 Materials

3.3.1 Seed

A newly developed high yielding variety of rapeseed, SAU Sarisha-1 developed by the Sher-e-Bangla Agricultural University; Dhaka was used in the experiment as a planting material. The seed was collected from the Department of Genetics and Plant

Breeding, Sher-e-Bangla Agricultural University, Dhaka. Before sowing, germination test was done in the laboratory and percentage of germination was over 95%.

3.3.2 Fertilizers

The recommended doses of K_2O, S, Zn & B at the rate of 100, 180, 5 and 10 kg/ha respectively were added to the soil of experimental field along with different levels of nitrogen & phosphorus. However, any fertilizer were not applied to control plot.

3.4 Methods

3.4.1 Treatments

Factor A: 4 levels of nitrogen (N kg/ha)			**Factor B: 4 levels of phosphorus (P_2O_5 kg/ha)**		
N_1	=	0	P_1	=	0
N_2	=	60	P_2	=	60
N_3	=	120	P_3	=	90
N_4	=	180	P_4	=	120

3.4.2 Design and layout

The experiment was laid out in a Randomized Complete Block Design (factorial) with three replications. The total plot number was 16 x 3 = 48. The unit plot size was 3 m x 2m= 6 m^2. The replications were separated from one another by 1.5 m. The distance between plots was 0.75 m.

3.4.3 Land preparation

The land was ploughed with a rotary plough and power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were cleaned properly. The final ploughing and land preparation were done on October 25, 2005.

3.4.4 Fertilization

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid required per plot were calculated. Half of urea and total amount of all other fertilizers of each plot were applied and incorporated into soil. Rest of the urea was top dressed after 30 days of sowing (DAS).

3.4.5 Sowing of seed

Sowing was done on 28 October, 2005 in rows 30 cm apart. Seeds were sown continuously in rows. The seeds were sown at a rate of 9 kg P/ha. After sowing; the seeds were covered with the soil and slightly pressed by hand.

3.4.6 Thinning and weeding

The optimum plant population (60 plants/m^2) was maintained by thinning excess plant at 15 DAS. The plant to plant distance was maintained as 5 cm. One weeding with khurpi was given on 25 DAS.

3.4.7 Irrigation

Two irrigations were given as plants required. First irrigation was given immediate after topdressing and second irrigation were applied 60 DAS. After irrigation when the plots were in zoe condition, spading was done uniformly and carefully to conserve the soil moisture.

3.4.8 Crop protection

As a preventive measure of aphid infestation, Malathion 57 EC @ 2 ml per litre of water was applied once at 50 DAS.

3.4.9 Harvesting and threshing

Crops were harvested when 80% of the siliquae in terminal raceme turned golden yellow in colour,. Ten plants were collected from different places of each plot leaving one meter square in the centre as well as boarder lines. After collecting sample plants, harvesting was started on February 10 and completed on February 20, 2006. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.4.9 Drying and weighing

The seeds and stovers thus collected were dried in the sun for couple of days. Dried seeds and stovers of each plot was weighed and subsequently converted into yield kg/ha.

3.5 Data collection

At harvesting, 10 plants were selected randomely from each plot to record the following data.

1. Plant height (cm)
2. Number of branches per plant
3. Number of sliquae per plant
4. Length of siliqua (cm.)
5. Number of seeds per siliqua
6. 1000-seed weight (g)
7. Seed yield per plant (g)
8. Seed yield per hectare (kg)

9. Stover yield per hectare (kg)

10. Biological yield per hectare (kg)

11. Harvest index (%)

12. Oil content (%)

13. Oil yield per hectare (kg)

3.5.1 Plant height (cm)

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

3.5.2 Number of branches per plant

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

3.5.3 Number of siliquae per plant

The number of siliquae from ten plants were counted and calculated as per plant basis.

3.5.4 Length of siliqua (cm)

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

3.5.5 Number of seeds per siliqua

Twenty siliquae were randomly taken from all siliqua and the seeds were counted. The number of seeds per siliqua was determined.

3.5.6 1000-seed weight (g)

A composite sample was taken from the yield of ten plants. The 1000-seeds of each plot were counted and weighed with a digital electric balance. The 1000-seed weight was recorded in gram.

3.5.7 Seed yield per plant (g)

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

3.5.8 Seed yield (kg/ha)

After threshing, cleaning and drying, total seed from harvested area (3.24 m^2) were recorded and was converted to kg ha^{-1}.

3.5.9 Stover yield (kg/ha)

After separation of seeds from plant, the straw and shell per harvested area was sun dried and the weight was recorded and then converted into kg/ha.

3.5.10 Biological yield (kg/ha)

The summation of seed yield and above ground stover yield per hectare was the biological yield.

3.5.11 Harvest index (%)

Harvest index was calculated by dividing the economic (seed) yield from the net plot by the total biological yield (seed+stover) from the same area (Donald, 1963) and multiplying by 100.

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

3.5.12 Oil content (%)

The oil content of seed was determined by Soxhlet method (Hughes, 1965) and expressed in percentage (%). This was done in Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701.

3.5.13 Oil yield (kg/ha)

Yield of oil was calculated from the percent oil in the seed samples multiplied by seed yield (kg/ha) and expressed in kg/ha.

3.6 Soil sampling

Three composite soil samples were collected within 15 cm depth of soil profile, taking one from each block at first ploughing. Each composite sample was a mixture of 10 samples obtained from ten different spots in each block. Collected samples were air dried and ground to pass a 10-mesh sieve and stored in polythene bags for laboratory analysis. Soil analysis was done at Soil Resources and Development Institute (SRDI).

3.7 Data analysis

The data obtained from the experiment were subjected to statistical analysis following analysis of variance technique (Russell, 1986). The mean differences were tested through least significant difference (LSD) method.

Chapter 4

RESULTS AND DISCUSSION

In this chapter, experimental results pertaining of the effects of different levels of nitrogen and phosphorus and their combinations on different components of rapeseed cv. SAU Sarisha-1 have been presented along with discussion in this chapter.

4.1 Plant height

4.1.1 Effect of nitrogen

The height of rapeseed plant at harvest was influenced significantly by different levels of nitrogen. Application of 120 kg N/ha produced taller plant (93.83 cm) and control treatment gave the lowest plant height (85.95 cm). Further increase in nitrogen level beyond 120 kg/ha could not improve plant height (Figure 1). These findings are in agreement with those of Singh *et al.* (2003), Tripathi and Tripathi (2003), Singh *et al.* (2002c), Tarafder and Mandal (1990). Similar were also obtained by Tomar *et al.* (1992), FAO, 1999, Ali and Ullah (1995), Shamsuddin *et al.* (1987), Ali and Rahman (1986) and Hassan and Rahman (1987).

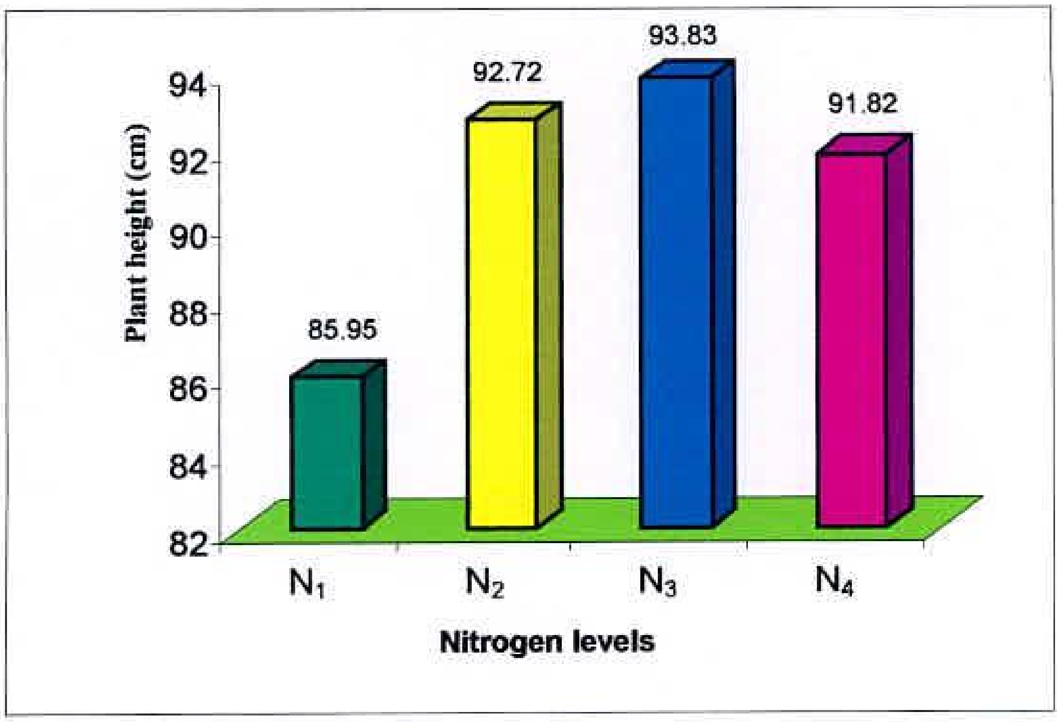


Fig. 1 Plant height of rapeseed cv. SAU Sarisha-1 at harvest as affected by nitrogen levels (LSD 0.05 = 5.39)

4.1.2 Effect of phosphorus

Application of phosphorus fertilizer significantly increased plant height. The tallest plant height (95.88 cm) was recorded from phosphorus at the rate of 90 kg P_2O_5/ha. The shortest plant height (88.30 cm) was recorded from control treatment. Likewise nitrogen level, more phosphorus dose could not improve plant height (Figure 2). These results agree with those of Tomer *et al.* (1997) who observed that the plant height increased significantly up to 80 kg P_2O_5/ha.

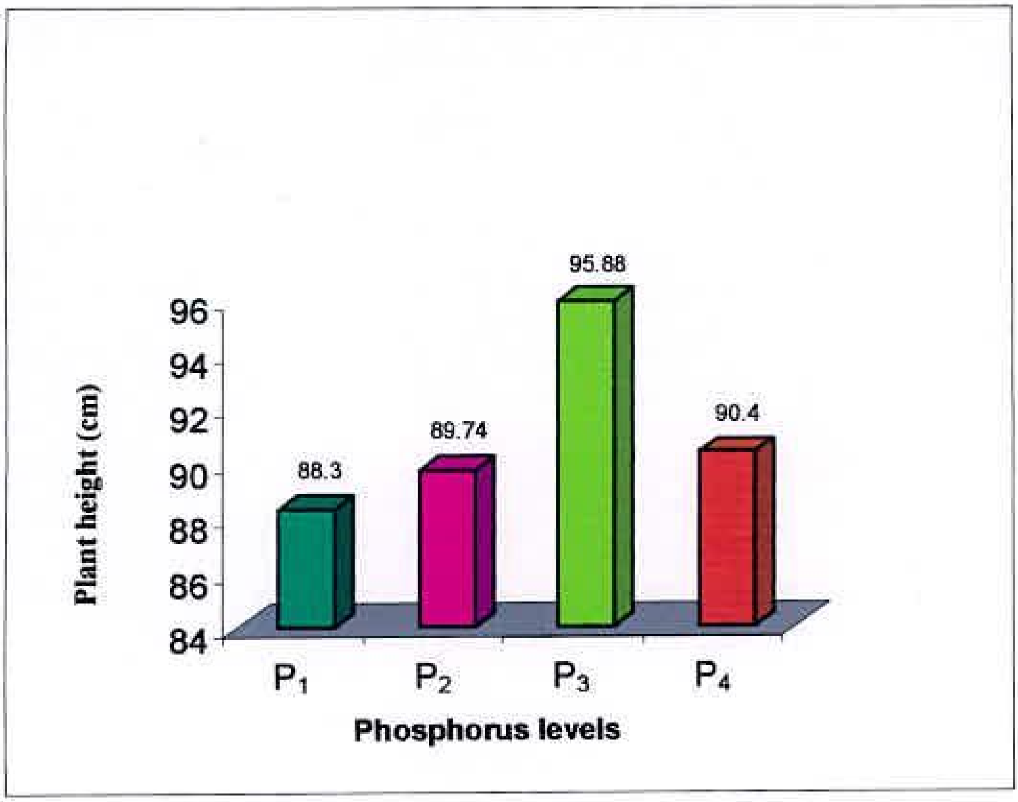


Fig. 2 Plant height of rapeseed cv. SAU Sarisha-1 at harvest as affected by phosphorus levels (LSD 0.05 = 5.39)

4.1.3 Combined effect of nitrogen and phosphorus

Figure 3 showed that the combination of nitrogen and phosphorus levels had significant effect on plant height. Nitrogen at the rate of 120 kg/ha along with 90 kg P_2O_5 ha^{-1} gave higher plant height (99.20 cm) which was followed by N_4P_3 &N_4P_1. Control treatment gave the lowest plant height (76.6 cm). Abedin *et al.(2003)*, Birbal *et al.*(2004), Brar *et al.*(1998) also obtained tatter plant by applying 120 kg N/ha and 70 kg P/ha.

The increase in plant height could be due to either cell elongation or cell multiplication or tissue differentiation or both of them which was influenced by optimum levels of fertilizers.

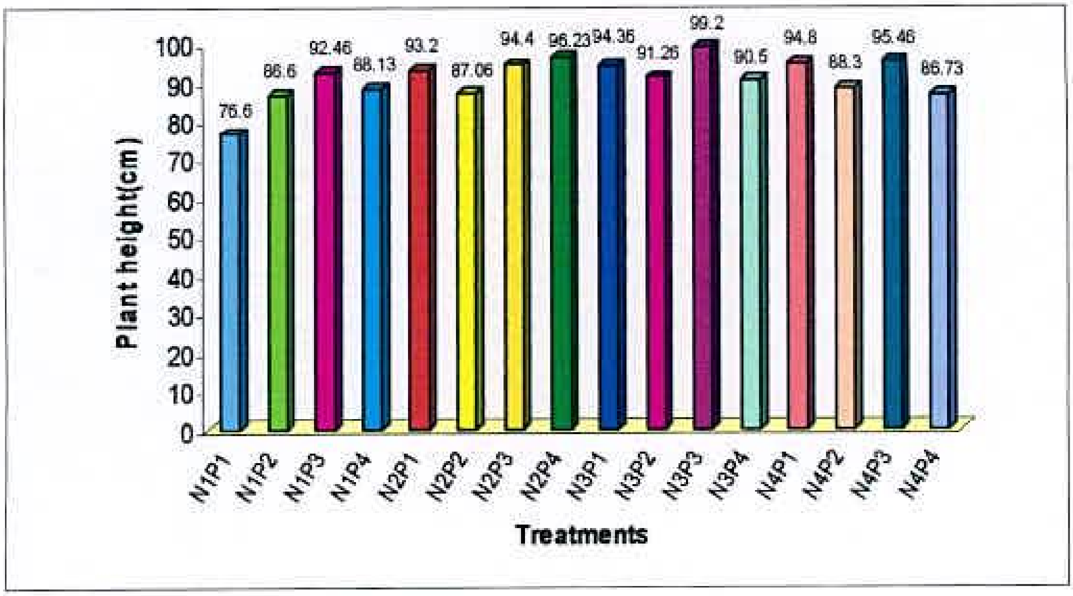


Fig.3 Combined effect of nitrogen and phosphorus levels on the plant height of rapeseed cv. SAU Sarisha-1 at harvest (LSD 0.05 = 10.79)

Yield attributes:

The response of yield attributes like number of branches per plant, siliquae per plant, length of siliqua, seeds per siliqua and 1000-seed weight of rapeseed cv. SAU Sarisha-1 following individual treatment of nitrogen and phosphorus levels and their combinations were found statistically significant (Figure 4, 5, 6 & Table 1).

4.2 Number of branches per plant

4.2.1 Effect of nitrogen

The influence of different levels of nitrogen fertilizer on the number of branches per plant was not significant (Figure 4). The N levels of 120 and 180 kg ha^{-1} did not show any significant differences regarding production of number of branches per plant. However, higher number (6.75) of branches per plant was obtained from 120 kg N ha^{-1} and lowest (5.75) from control treatment. Mondal and Gaffer (1983) also reported that nitrogen fertilizer application had no significant effect on number of primary branches per plant of rapeseed, Tomar *et al.*(1997), Tomer *et al.*(1992), Ali and Ullah (1995), Ali and Rahman (1986) and Shamsuddin *et al.*(1987) also obtained highest number of branches per plant with 120 kg N ha^{-1}.

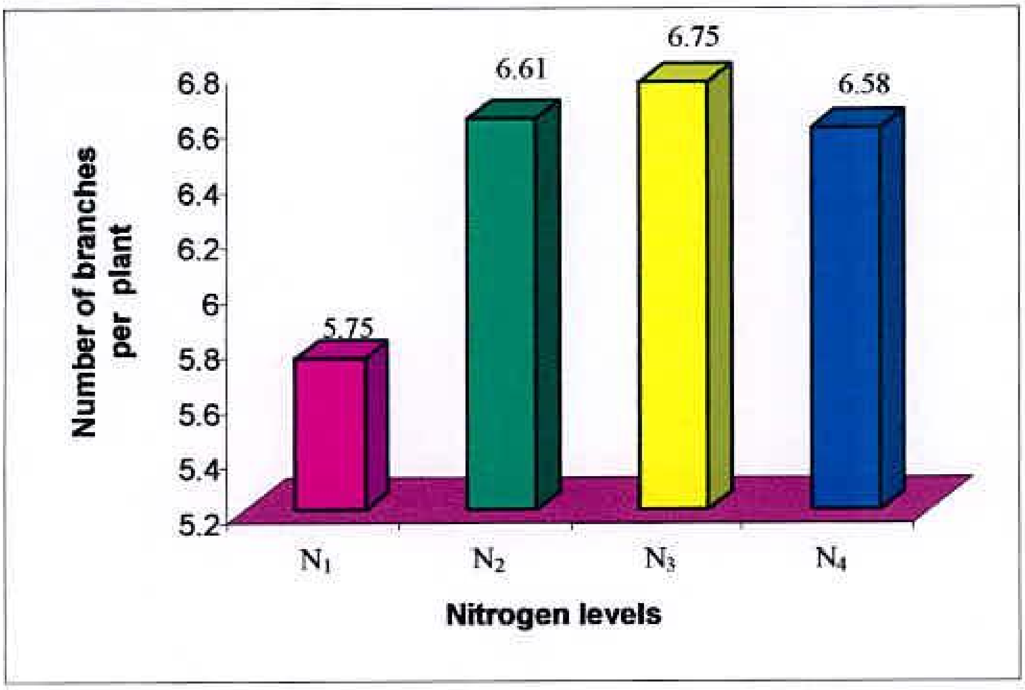


Fig. 4 Number of branches per plant of rapeseed cv.SAU Sarisha-1 at harvest as affected by nitrogen levels (LSD 0.05= NS)

4.2.2 Effect of phosphorus

From Figure 5 t was visualized that different treatments of phosphorus levels had no significant effect on production of branches per plant. However, higher number of branches per plant (6.75) was obtained at 90 kg P_2O_5 ha^{-1} and the lowest number of branches per plant (6.0) at control treatment. Chaubey *et al.*(2001) obtained significantly higher number of branches per plant by applying P_2O_5 up to 60 kg/ha. But Davaria *et al.* (2001) reported higher number of branches per plant from 50 kg P_2O_5/ha.

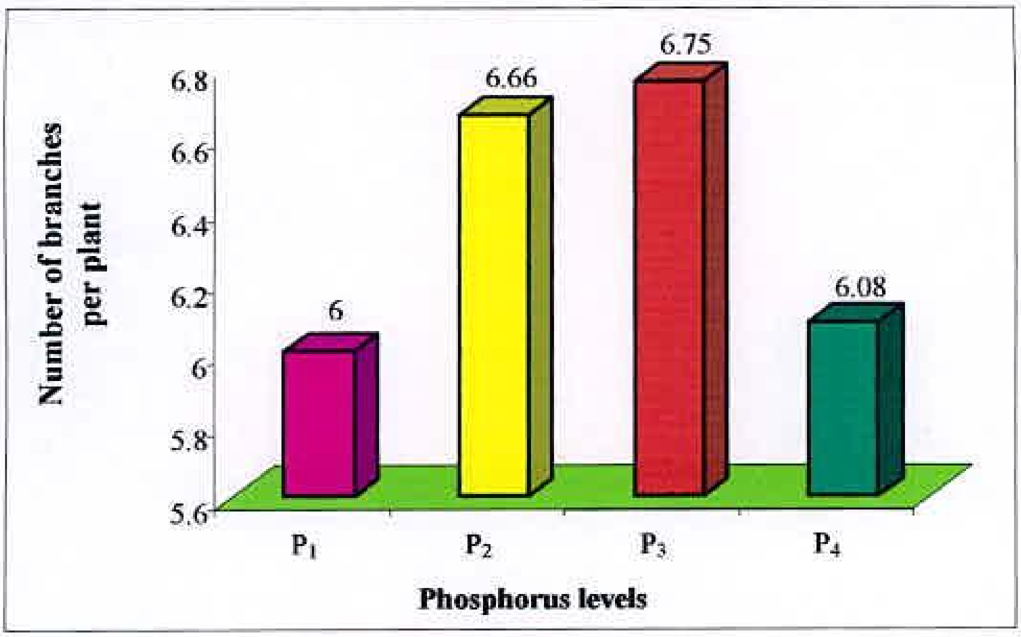


Fig. 5 Number of branches per plant of rapeseed cv. SAU Sarisha-1 at harvest as affected by phosphorus levels (LSD 0.05= NS)

4.2.3 Combined effect of nitrogen and phosphorus

It was observed that combined effect of nitrogen and phosphorus did not show any significant differences to produce branches per plant. The application rate of N 120 kg/ha and P_2O_5 90 kg/ha produced higher number branches per plant (7.66) and control treatment produced lowest number of branches per plant (5.33) (Figure 6).

Probably the combination of N 120 kg/ha and P_2O_5 90 kg/ha supported plant to grow vigorously with maximum production of dry matter. Thus maximum number of branches was evident.

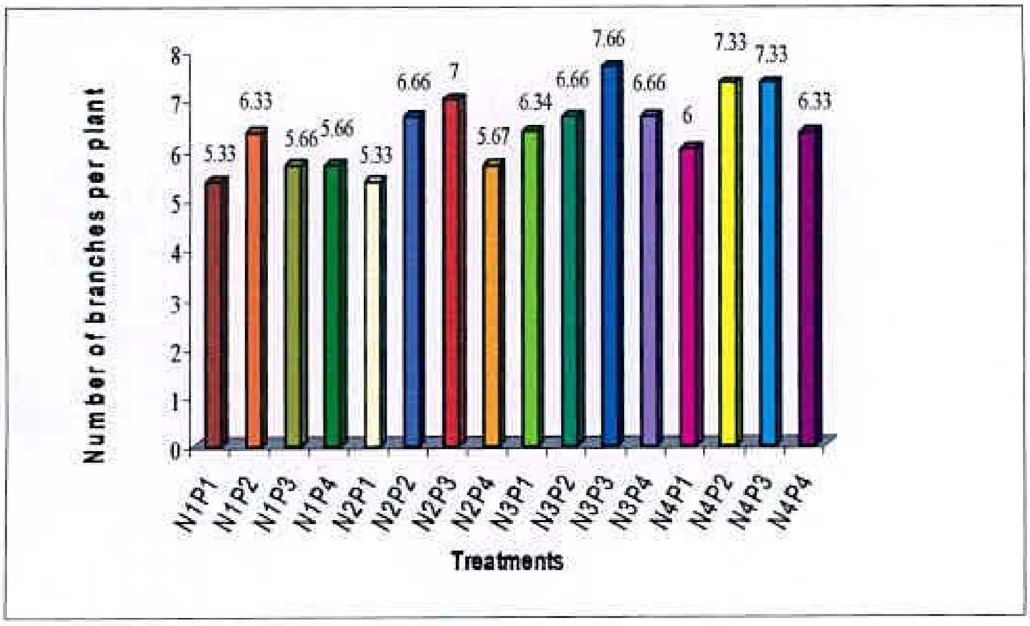


Fig. 6 Combined effect of nitrogen and phosphorus levels on the number of branches per plant of rapeseed cv. SAU Sarisha-1 at harvest (LSD 0.05= NS)

4.3 Number siliquae per plant

4.3.1 Effect of nitrogen

Number of siliquae per plant is one of the most important yield contributing characters in rapeseed. The number of siliquae per plant was significantly affected by different levels of nitrogen fertilizers. Table 1 showed that number of siliquae per plant increase with the increase level of nitrogen up to 120 kg/ha and then decline. The highest number of siliqua per plant (117.36) was recorded at 120 kg N/ha which was significantly different from other levels of nitrogen. The lowest number of siliquae per plant was recorded from without nitrogen. Similar result also obtained by Shukla *et al.*(2002 b), Singh *et al.* (2003), Singh *et al.* (2002 c), Tarafder and Mondal (1990) and Shamsuddin *et al.* (1987) in rapeseed.

Table 1 Yield attributes of rapeseed cv. SAU Sarisha-1 as affected by nitrogen levels, phosphorus levels and their combined effect

Treatments	Siliqua per plant (No.)	Length of siliqua (cm)	Seeds per siliqua (No.)	1000-seed weight (g)
Nitrogen levels				
N_1	71.89	5.88	18.63	2.34
N_2	95.32	5.98	21.14	2.44
N_3	117.35	6.36	23.52	3.15
N_4	106.70	5.64	19.89	2.64
LSD at 5%	**7.37**	**0.45**	**2.18**	**0.44**
Phosphorus levels				
P_1	86.13	5.60	18.71	2.22
P_2	93.96	5.98	20.42	2.66
P_3	109.19	6.34	23.04	3.14
P_4	101.80	5.92	21.00	2.56
LSD at 5%	**7.37**	**0.46**	**2.17**	**0.44**
Nitrogen x Phosphorus				
N_1P_1	59.23	4.90	14.40	1.36
N_1P_2	60.33	5.93	18.00	2.77
N_1P_3	90.67	5.86	20.73	2.68
N_1P_4	77.33	6.13	21.40	2.57
N_2P_1	76.10	6.06	19.73	2.40
N_2P_2	94.37	6.06	22.27	2.48
N_2P_3	104.3	6.10	23.10	2.66
N_2P_4	106.6	5.70	22.43	2.23
N_3P_1	106.3	6.03	19.87	2.69
N_3P_2	102.0	5.50	20.93	2.88
N_3P_3	132.6	7.56	29.67	3.36
N_3P_4	109.3	6.36	20.67	2.68
N_4P_1	103.7	6.23	20.87	2.42
N_4P_2	119.2	5.60	20.50	2.53
N_4P_3	109.2	5.93	18.67	2.88
N_4P_4	114.0	5.50	19.53	2.76
LSD at 5%	**14.74**	**0.90**	**4.35**	**0.88**
CV%	**6.71**	**6.77**	**9.33**	**6.24**

4.3.2 Effect of phosphorus

The highest number of siliquae per plant (109.19) resulted from 90 kg P_2O_5/ha and the lowest number of siliquae (86.31) was obtained from the control treatment with a difference of 26.77%. Further increase in phosphorus level could not increase number of siliquae per plant (Table 1). Tomer *et al.* (1997) observed that siliquae per plant increased significantly up to 80 kg P_2O_5/ha and Davaria (2001) obtained the heighest number of siliquae per plant with 50 kg P_2O_5/ha which are close agreement with the results.

4.3.3 Combined effect of nitrogen and phosphorus

Nitrogen and phosphorus showed significant effect on number of siliquae per plant. The highest number of siliquae per plant (132.60) was produced with the interaction of 120 kg N and 90 kg P_2O_5/ha. Lowest number of siliquae per plant (59.23) was given by the control combination (Table 1). Sharawat *et al.*(2002) also obtained highest number of siliquae per plant produced with the interaction of 120 kg N/ha and 90 kg P_2O_5/ha.

Siliquae per plant is an important yield contributing character which has a great effect on final yield. The combination of 120 kg N/ha and 90 kg P_2O_5 /ha supported plant to maximum production of dry matter and number of siliquae per plant which could positively influenced the higher dry matter production.

4.4 Length of siliqua

4.4.1 Effect of nitrogen

Length of siliqua of mustard was significantly influenced by different levels of nitrogen. It was observed that 120 kg N/ha gave highest siliqua length (6.36 cm) and control gave the lowest one (5.88cm) (Table 1). Here, N_1 and N_4 treatment gave the statistically similar results. Singh (2002), Shukla *et al.* (2002 b), Singh *et al.* (2002 c) also reported the highest length of siliqua at the rate of 120 kg N/ha.

4.4.2 Effect of phosphorus

Siliqua length of rapeseed was significantly increased by different levels of phosphorus (Table 1). Phosphorus fertilizer at the rate of 90 kg P_2O_5/ha produced the higher siliqua length (6.34 cm) and control treatment produced the shortest one (5.60 cm). Similer results were obtained by Chaubey *et al.* (2001) observed that phosphorus at the rate of 60 kg P_2O_5/ha significantly increased siliqua length of rapeseed. Singh (2002) also observed that application of phosphorus increased length of siliqua of mustard.

4.4.3 Combined effect of nitrogen and phosphorus.

Nitrogen and phosphorus interaction had significant effect on siliqua length. The combination of nitrogen and phosphorus at the rate of 120 and 90 kg/ha produced the highest siliqua length (7.56 cm) and control treatment gave the shortest siliqua length (4.90 cm) with a difference of 54.28% (Table 1). Verma *et al.* (2003) also obtain similar results.

4.5 Number of seeds per siliqua

4.5.1 Effect of nitrogen

Table 1 shows the effects of different levels of nitrogen fertilizer on the number of seeds per siliqua. Number of seed per siliqua varied significantly with different levels of nitrogen fertilizer. Increasing rate of nitrogen significantly increased the number of seeds per siliqua up to 120 kg/ha. Applying nitrogen 120 kg/ha gave the highest number of seeds per siliqua (23.52) and the lowest number of seeds per siliqua (18.63) was obtained in control treatment but identical to without level of Nitrogen. Higher N rates increased the number of seeds per siliqua in Brassica spp. (Allen and Morgen, 1972 and Scott *et al.*, 1973). Singh *et al.*, (1985) also reported that nitrogen level at 120 kg ha^{-1} increased the number of seeds per siliqua in *B. juncea.* Grewall and Kolar (1990) also observed that nitrogen at 100 kg/ha increased the number of seeds per siliqua in *B. juncea.*

4.5.2. Effect of phosphorus

Phosphorus fertilizer had significant effect on number of seeds per siliqua. Phosphorus at the rate of 90 kg P_2O_5/ha^{-1} produced the highest number of seeds per siliqua (23.04) but the lowest one (18.71) was obtained from control treatment with a difference of 23.14%. Further increase in phosphorus level beyond 120 kg/ha could not improve seeds $siliqua^{-1}$ (Table 1). Birbal *et al.* (2004) observed that seeds $siliqua^{-1}$ increased significantly at the rate of 75 kg P/ha but Davaria *et al.* (2001) reported lower level of P_2O_5 (50 kg/ha) gave the higher seeds per siliquae.

4.5.3 Combined effect of nitrogen and phosphorus

It was also observed that treatment combination of nitrogen and phosphorus had significant effect on number of seeds per siliqua. Nitrogen at the rate of 120 kg/ha with 90 kg P_2O_5/ha produced the highest number of seeds per siliqua (29.67) and control treatment gave the lowest one (14.40) with a difference of 106.04% (Table 1). Chaubey *et al.* (2001) and Patel (1998) who obtained similar results. It is noted that with the increase of P level without N showed higher seeds per siliqua but higher level of N with P decrease the parameter.

The fertilizer combination probably influenced the partition of dry matter towards number of seeds per plant.

4.6 1000-seed weight

4.6.1 Effect of nitrogen

Different levels of N fertilizer had significant effect on 1000-seed weight of rapeseed (Table 1). Application of nitrogen at different levels significantly increased the 1000-seed weight up to 120 kg/ha which produced maximum seed weight (3.15g) without nitrogen treatment gave the lowest one (2.34 g) but statistically as per to N_2 and N_4. Ozer (2003), Singh *et al.*, (2002), Shukla *et al.*, (2002 b) and Shamsuddin *et al.* (1987) also obtained highest 1000-seed weight with 120 Kg N/ha but Sharma and Jain (2002) obtained highest 1000-seed weight at 80 kg N/ha.

4.6.2 Effect of phosphorus

From Table 1, it revels that the phosphorus levels had significant effect on 1000-seed weight. The application of phosphorus significantly increased 1000-Seed weight. Application of 90 Kg P_2O_5 ha^{-1} gave the highest 1000-seed weight (3.14 g) where as control treatment gave the lowest (2.22 g) 1000-seed weight. Further increase in phosphorus level beyond 90 kg/ha could not improve the seed weight. Birbal (2004) obtained significant effect on 1000-seed weight and highest 1000 seed weight was recorded from at 75 kg P/ha. But Davaria *et al.* (2001) observed lower level of P_2O_5 (50 kg/ha) increased 1000-seed weight.

4.6.3 Combined effect of nitrogen and phosphorus

It was also observed that treatment combination of nitrogen and phosphorus had significant effect on 1000-seed weight. The highest 1000-seed weight (3.36 g) was recorded with the interaction of 120 kg N and 90 kg P_2O_5/ha. Lowest 1000-seed weight (1.36 g) was recorded from control treatment which was a difference of 147.79% (Table 1). The 1000-seed weight increased with the increasing levels of nitrogen and phosphorus as reported by Sharawat *et at.*, (2002), Singh *et al.*,(1996), Kantwa and Meena (2002).

Yields and harvest index

Application of nitrogen levels, phosphorus levels and their combination on yields and harvest index of rapeseed cv. SAU Sarisha-1 showed in table 2 and discussed briefly.

Table 2 Yields and harvest index of rapeseed cv. SAU Sarisha-1 as affected by nitrogen levels , phosphorus levels and their combined effects

Treatments	Seed yield per plant (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Nitrogen levels					
N_1	1.35	1064.45	1560.54	3779.75	24.64
N_2	3.06	1299.40	3141.92	4491.25	29.10
N_3	3.82	1510.34	3862.17	4620.00	32.73
N_4	2.86	1122.57	3623.55	4223.75	29.12
LSD at 5%	**0.54**	**345.3**	**486.5**	**20.83**	**2.67**
Phosphorus levels					
P_1	2.02	698.64	2566.01	2347.00	26.31
P_2	2.82	1333.79	3150.36	4475.25	29.34
P_3	3.48	1702.34	3353.72	5403.00	31.96
P_4	2.48	1266.00	3118.10	4889.50	27.89
LSD at 5%	**0.54**	**345.3**	**486.5**	**20.54**	**2.67**
Nitrogen x Phosphorus					
N_1P_1	1.15	403.10	593.26	1595.00	25.75
N_1P_2	1.47	764.16	2250.29	2421.00	29.50
N_1P_3	1.63	1000.33	1820.41	3250.20	30.80
N_1P_4	1.16	626.96	1578.22	4396.00	30.43
N_2P_1	2.93	1216.26	2716.33	4208.00	30.82
N_2P_2	3.34	1322.30	2886.41	5196.17	31.46
N_2P_3	3.24	1478.86	3531.72	5031.00	31.91
N_2P_4	2.72	1317.73	3433.21	5476.00	30.19
N_3P_1	3.35	1545.63	3650.61	3932.15	28.55
N_3P_2	3.09	1403.33	3461.10	5010.00	29.62
N_3P_3	5.95	2196.60	4485.56	5800.00	38.47
N_3P_4	2.90	1333.80	3851.43	4849.13	25.91
N_4P_1	2.49	1092.80	3303.80	2122.00	20.13
N_4P_2	3.40	1471.66	4003.66	4751.00	26.77
N_4P_3	3.12	1271.73	3577.20	5185.19	26.65
N_4P_4	2.42	1227.80	3609.56	4837.09	25.02
LSD at 5%	**1.09**	**687.5**	**971.21**	**41.67**	**5.34**
CV%	**17.56**	**14.64**	**14.22**	**0.58**	**8.24**

4.7 Seed yield per plant

4.7.1 Effect of nitrogen

In the present study, significant variation was found in seed yield per plant at different nitrogen levels (Table 2). Among the treatments, N_2 and N_4 gave the statistically similar results. The rate of nitrogen at 120 kg/ha significantly produced highest seed yield per plant (3.82 g) and control treatment gave the lowest seed yield per plant (1.36 g) with a difference of 180.88%. Seed yield increased with the increasing rates of nitrogen fertilizer up to 120 kg/ha and then declined. The higher seed yield per plant was also obtained with same nitrogen rate as reported by Singh *et al.* (1998); Tateja *et al.*, (1996).

4.7.2 Effect of phosphorus

Seed yield per plant was significantly influenced by phosphorus levels (Table 2). Application of phosphorus at 90 kg/ha significantly increased the seed yield per plant (3.48 g) over all other doses and control treatment gave the lowest one(2.02 g), with a difference of 72.27%. Arthamwar *et.a.l* (1996) also reported that application of phosphorus significantly increased the seed yield with 80 kg P_2O_5/ha. Singh (2002) also obtained similar results.

4.7.3. Combined effect of nitrogen and phosphorus

Nitrogen and phosphorus combination had significant effect on seed yield per plant. The combination of nitrogen and phosphorus at the rate of 120 and 90 kg/ha produced the highest seed yield per plant (5.95 g) and control gave the lowest seed yield per plant (1.15 g) with a difference of 417.39% (Table 2).

Seed yield per plant is a complex character which depends on the different yield contributing characters such as number of branches per plant, number of siliqua per plant, number of seeds per plant and 1000-seed weight.

In previous discussion it showed that this combination produced the highest number branches per plant, siliqua per plant, seeds per siliqua and 1000- seed weight which cumulatively increased the seed yield per plant.

4.8 Seed yield

4.8.1 Effect of nitrogen

In the present study, significant variation was found in seed yield at different nitrogen levels (Table 2). The rate of nitrogen at 120 kg/ha produced highest seed yield (1510.34 kg/ha) and control treatment gave the lowest seed yield per hectare (1064.45 kg/ha) with a difference of 41.88%. Further increase in nitrogen level beyond 120 kg/ha could not improve the seed yield. The higher seed yield/ha was also obtained with same nitrogen rate reported by Sing and Prasad (2003). Singh *et al.* (2003), Shukla *et al.* (2002 b), Singh (2002), Shukla *et al.* (2002a), Singh *et al*, (2002c), Shukla and Kumar (1997), Tuteja *et al.* (1996), Shamsuddin *et al.* (1987). But 80 kg N/ha also gave highest seed yield/ha as reported by Singh (2004), Sharma and Jain (2002), Ghosh *et al* (2001), Khan *et al.* (2003), Singh *et al.* (1998), Thakuria and Gogoi (1996).

4.8.2 Effect of phosphorus

Table 2 showed significant variation in seed yield among the phosphorus levels. Phosphorus at the rate of 90 kg P_2O_5/ha gave the highest seed yield (1702.34 kg/ha) and seed yield decreased with the decreasing or increasing application of phosphorus fertilizer than 90 kg P_2O_5. Seed yield was lowest (698.64 kg/ha) at control treatment. The seed yield was increased 143.66% over control. Sumeria (2003) reported that seed yield of Indian mustard increased with 60 kg p/ha. But Davaria *et al.* (2001) found that seed yield was highest with 50 kg P_2O_5/ha^{-1}.

4.8.3 Combined effect of nitrogen and phosphorus

It was revealed that nitrogen and phosphorus combination influenced the seed yield per hectare and seed yield was significantly superior (2196.60 kg/ha) at 120 kg N with 90 kg P_2O_5/ha. But control treatment gave the lowest seed yield (403.10 kg/ha). The increased seed wield over control was 377.94 % (Table 2). Among the treatments N_3P_3 was statistically different from other treatments. Sharawat *et al.* (2002), Chaubey *et al.* (2001) observed significantly higher seed yield at 120 kg N/ha in combination with 60 kg P_2O_5/ha. Tomar *et al.* (1996) reported that application of 90 kg N/ha and 80 kg P_2O_5/ha significantly increased seed yield.

4.9 Stover yield

4.9.1 Effect of nitrogen

The nitrogen application favorably influenced the stover yield and the difference among the consecutive levels was significant (Table 2). The application of 120 kg N/ha gave significantly highest stover yield (3862.17 kg/ha) and control treatment gave the lowest stover yield (1560.54 kg/ha) with a difference of 147.48%. Further increase in nitrogen levels could not improve stover yield. These findings were an agreement with that of Singh and Prasad (2003), Singh *et al.* (2002c). But Meena *et al.* (2002) observed higher stover yield of mustard at the nitrogen rate of 60 kg/ha.

4.9.2 Effect of phosphorus

Stover yield was significantly influenced by different levels of phosphorus. Application of phosphorus at the rate of 90 kg/ha gave the highest stover yield (3353.72 kg/ha) and control treatment produced the lowest one (2566.01 kg/ha) with a difference of 30.69% (Table 2). Among the treatments P_2, P_3 and P_4 gave the statistically similar results. Patel and Shelke (1999) observed a similar trend of stover yield.

4.9.3 Combined effect of nitrogen and phosphorus

Nitrogen and phosphorus combination had significant effect on stover yield. Stover yield was highest (4485.56 kg/ha) when 120 kg N was applied with 90 kg P_2O_5/ha (Table 2) which was statistically different from control treatment. The lowest stover yield (593.26 kg/ha) observed by control treatment. Stover yield increased with the increased levels of nitrogen up to 120 kg/ha and phosphorus up to 80 kg/ha reported by Singh *et al.* (1996); Mina *et al.* (2003).

Plants were influenced following the suitable combination of N & P thus producing greater amount of growth & yield components resulted in increased stover yield.

4.10 Biological yield

4.10.1 Effect of nitrogen

From Table 2 it would be seen that the different nitrogen levels had significant effect on biological yield. Application of nitrogen at 120 kg/ha significantly increased the biological yield (4620 kg/ha) and control treatment produced lowest biological yield (3779.75 kg/ha) with a difference of 22.23%. These are in agreement of Saran and Giri (1990) and Chowdhury *et al.* (1991).

4.10.2 Effect of phosphorus

Different phosphorus levels produced significant variation in biological yield of rapeseed cv. SAU Sarisha-1 (Table 2). The highest biological yield (5403 kg/ha) was obtained from the rate of 90 kg P_2O_5/ha and biological yield decreased when phosphorus levels increased or decreased than this level. In this case control treatment produced the lowest one (2347 kg/ha). Sharma and Singh (2003) reported that application of phosphorus significantly increased the biological yield.

4.10.3 Combined effect of nitrogen and phosphorus.

Table 2 showed that the combined effect of nitrogen and phosphorus levels influenced the biological yield in the present study. The treatments with 120 kg N/ha with 90 kg P_2O_5/ha produced the highest biological yield (5800 kg/ha) and control treatment gave the lowest yield (1595 kg/ha) with a difference of 263.63% .

4.11 Harvest index

4.11.1 Effect of nitrogen

From Table 2 it was revealed that the different nitrogen levels had significant effect on harvest index. Application of nitrogen at 120 kg/ha significantly increased the harvest index (32.73%) and control treatment gave lowest one (24.64%) with a difference of 30.29%. Among the treatments N_2 and N_4 gave the statistically similar results. Similar result was also observed by Shukla and Kumar (1997) at the same nitrogen level.

4.11.2 Effect of phosphorus

Harvest index was influenced by different levels of phosphorus. The highest harvest index (31.96%) was obtained from the rate of 90 kg P_2O_5/ha and the lowest

(26.31%) obtained from control treatment (Table 2). Among the treatments P_2 and P_3 gave the statistically similar results.

4.11.3 Combined effect of nitrogen phosphorus

Combination between nitrogen and phosphorus levels may be important determining factor for harvest index. Harvest index was significantly higher (38.47%) when applied 120 kg N in combination with 90 kg P_2O_5/ha which was statistically different from other treatments. The lowest harvest index (25.75) (Table 2) was recorded from the control treatment which was 49.39% lower than the highest index values.

4.12 Oil content

4.12.1 Effect of nitrogen

In this study oil content was not significantly influenced by different nitrogen levels. From Figure 7 revealed that application of N at 120 kg/ha gave the maximum oil content (41.38%) and control treatment gave the lowest oil content (41.09%). Singh *et al.* (2004) also reported that nitrogen application did not affect the oil content of rape seed.

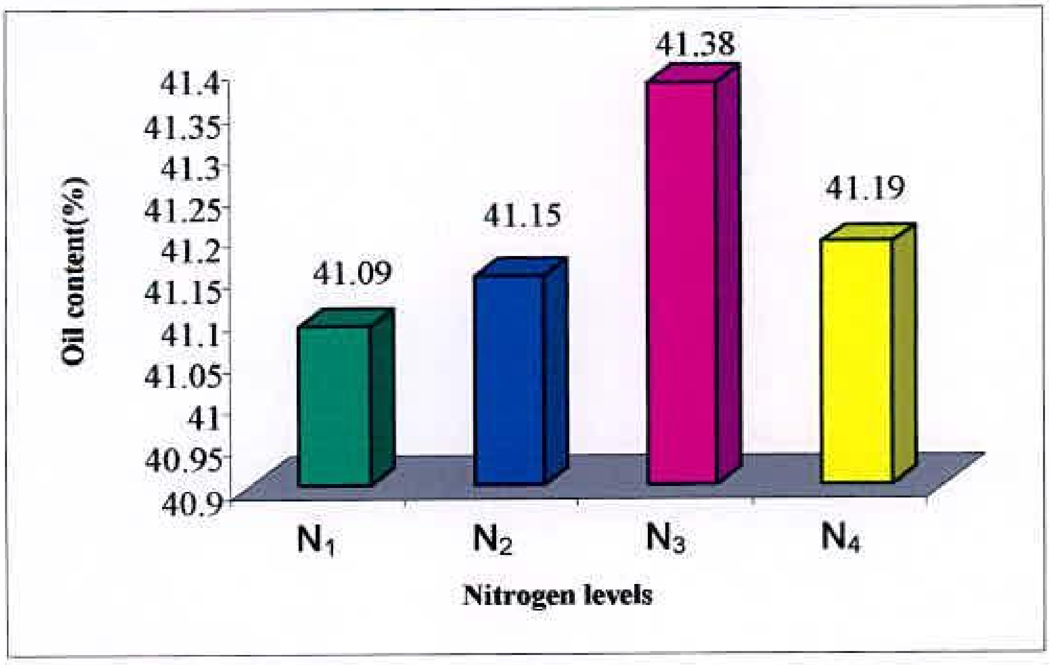


Fig. 7 Oil content of rapeseed cv. SAU Sarisha-1 seed as affected by nitrogen levels(LSD 0.05=NS)

4.12.2 Effect of phosphorus

Phosphorus had significant effect on oil content in rapeseed. Phosphorus application at 90 kg P_2O_5/ha indicated highest oil content (41.59%) and control treatment gave the lowest oil content (40.56%) (Figure 8). Here, 120 kg P_2O_5, 90 kg P_2O_5 and 60 kg P_2O_5/ha gave the statistically similar results. Arthmwar *et al.* (2003) reported that increase in the phosphorus level up to 80 kg/ha significantly improved oil content of Indian mustard.

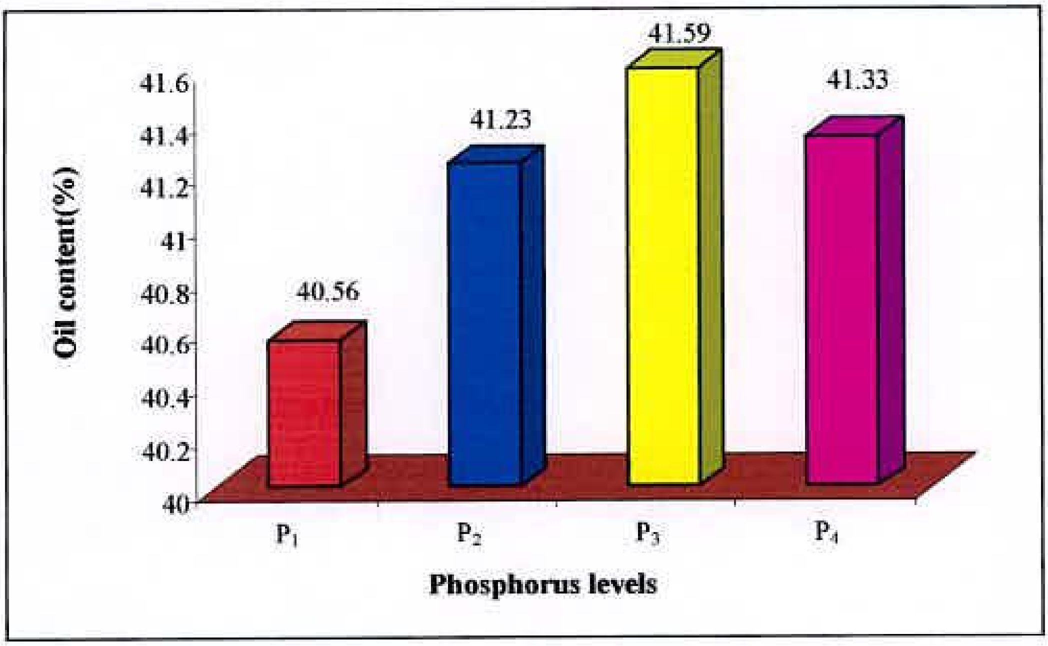


Fig. 8 Oil content of rapeseed cv.SAU Sarisha-1 seed as affected by phosphorus levels (LSD 0.05=0.72)

4.12.3 Combined effect of nitrogen and phosphorus

Oil content had significant response to nitrogen along with phosphorus fertilization. It was observed that 120 kg N with 60 kg P_2O_5/ha gave the highest oil content (42.36%) and lowest oil content (38.70%) observed in control treatment (Figure 9). Singh and Meena (2003) also obtained highest oil content with the increasing levels of nitrogen and phosphorus and they found that nitrogen at 120 kg with 60 kg P/ha gave the highest oil content.

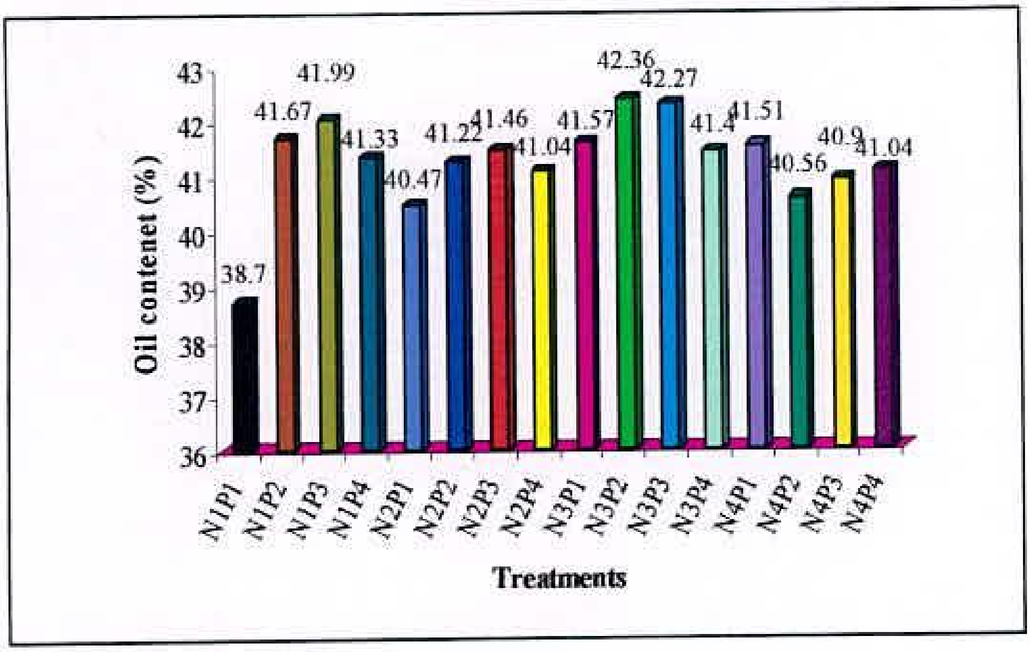


Fig. 9 Oil content of rapeseed cv. SAU Sarisha-1 seeds as affected by combination of nitrogen and phosphorus levels (LSD 0.05=1.44)

4.13 Oil yield

4.13.1 Effect of nitrogen

The effect of nitrogen on oil yield of rapeseed was found significant. Nitrogen at 120 kg/ha produced maximum oil yield (674.77 kg/ha) compared to 60 and 180 kg N/ha and the lowest oil yield (294.24 kg/ha) found in control treatment (Figure 10). Ali and Ullah (1995) also observed higher oil yield (369 kg/ha) at the same nitrogen fertilization.

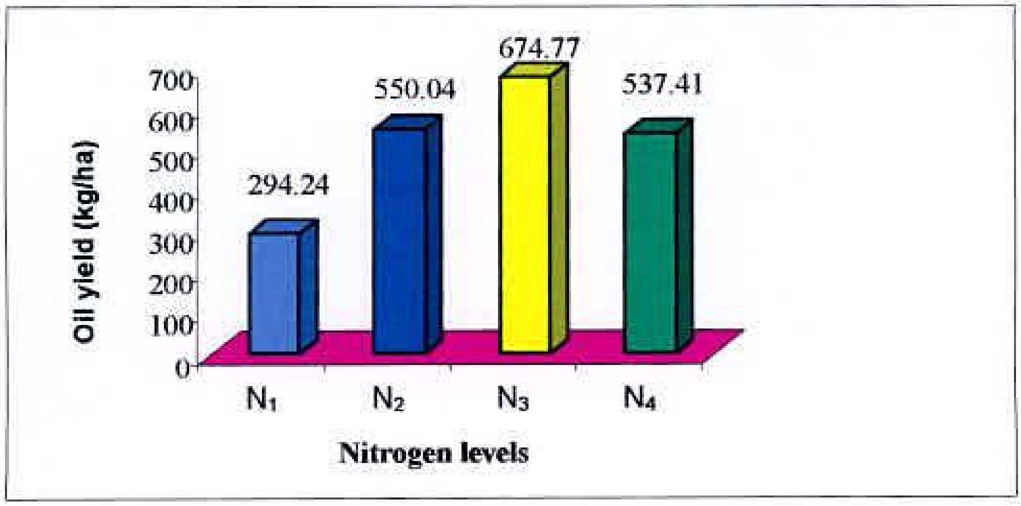


Fig. 10 Oil yield of rapeseed cv. SAU Sarisha-1 seed as affected by nitrogen levels (LSD 0.05=132.7)

4.13.2 Effect of phosphorus

Phosphorus was also significant effect on oil yield of rapeseed. Each successive increase of phosphorus level up to 90 kg/ha increased the oil yield. It was observed from Figure 11 that 90 kg P_2O_5/ha gave the highest oil yield (596.18 kg/ha) and control treatment gave the lowest oil yield (442.70 kg/ha).

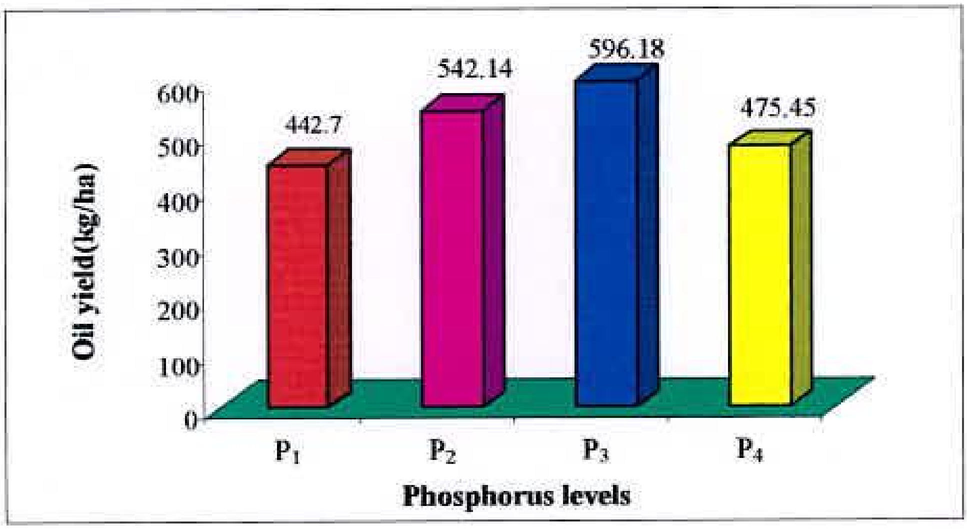


Fig.11 Oil yield of rapeseed cv. SAU Sarisha-1 seed as affected by phosphorus levels (LSD 0.05=132.7)

4.13.3 Combined effect of nitrogen and phosphorus

It was revealed from Figure 12 that the treatment combination of nitrogen and phosphorus had significant effect on oil yield of rapeseed. Nitrogen at 120 kg/ha with 90 kg P_2O_5/ha produced highest oil yield (836.15 kg/ha) and lowest oil yield (176.26 kg) was observed in control combination.

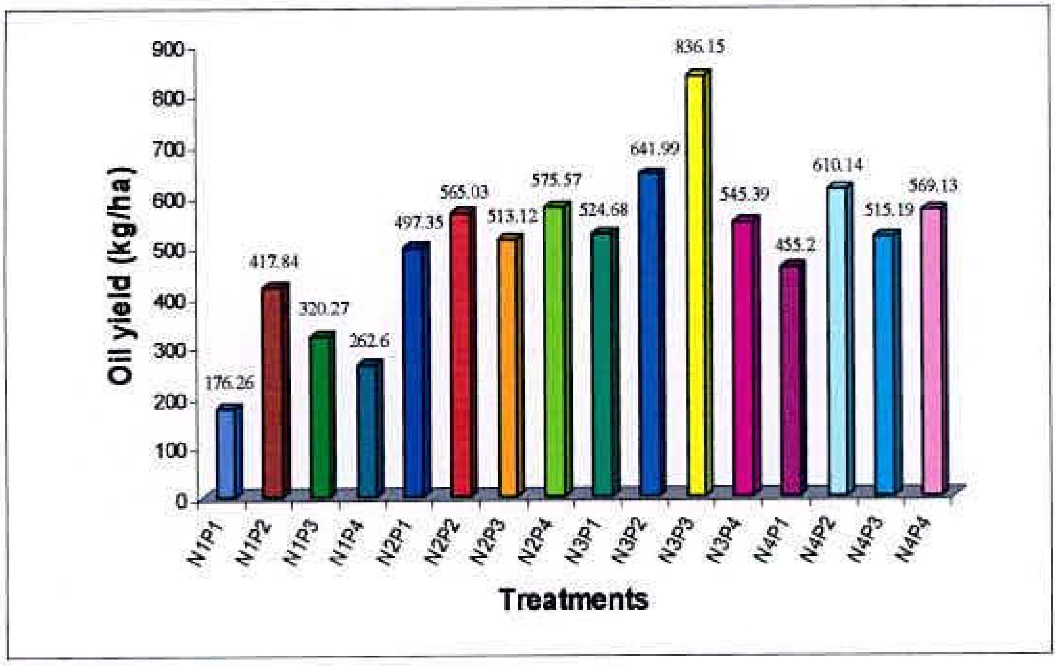


Fig. 12 Oil yield of rapeseed cv. SAU Sarisha-1 seeds as affected by combination of nitrogen and phosphorus levels (LSD 0.05=265.4)

Chapter 5
SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka-1207 during Rabi season (October-February) of 2005-2006 to study the effect of nitrogen and phosphorus levels on the yield, yield contributing characters and seed quality of rapeseed cv. SAU Sarisha-1. The results of the experiment are summarized below.

The increased plant height was observed up to 120 kg N/ha. The maximum plant height was found from 90 kg P_2O_5/ha. Treatment combination of 120 kg N and 90 kg P_2O_5/ha showed tallest plants.

The number of branches per plant did not changed significantly with different levels of nitrogen and phosphorus. The treatment combination of 120 kg N and 90 kg P_2O_5/ha produced highest number of branches (7.66) per plant.

Number of siliquae per plant varied significantly with nitrogen and phosphorus levels. Every increased level of nitrogen and phosphorus increased siliquae per plant at certain level (up to 120 kg N and 90 kg P_2O_5/ha) and decreased with further increased levels of the nutrients. Combined effect of nitrogen and phosphorus also significantly influenced the siliquae per plant. Application of 120 kg N/ha along with 90 kg P_2O_5/ha gave the highest number of siliquae per plant (132.60).

The levels of nitrogen had shown significant effect on the siliqua length, seeds per siliqua, weight of 1000-seed. The highest siliqua length (6.36 cm), seeds per siliqua

(23.52) and 1000-seed weight (3.15 g) obtained at 120 kg N/ha. Similarly phosphorus had significant effect on the siliqua length, seeds per siliqua and, 1000-seed weight. Phosphorus at the rate of 90 kg P_2O_5/ha gave highest siliqua length (6.37cm), seeds per siliqua (23.04) and 1000-seed weight (3.14 g). The highest siliqua length (7.56 cm), seeds per siliqua (29.67) and weight of 1000-seed (3.36 g) were obtained at 120 kg N/ha in combination with 90 kg P_2O_5/ha.

Seed yield plant^{-1} is a complex character which depends on the different yield contributing characters.The treatment 120 kg N/ha produced the highest seed yield plant^{-1} (3.82 g). This yield was significantly influenced by phosphorus levels and 90 kg P_2O_5/ha produced highest seed yield plant^{-1} (3.48 g). The combination of 120 kg N/ha with 90 kg P_2O_5/ha produced the highest seed yield plant^{-1} (5.95 g).

The seed yield ha^{-1} was increased significantly up to 120 kg N/ha. Nitrogen level at 120 kg/ha increased the seed yield ha^{-1} by 41.88% over control. Highest seed yield ha^{-1} of rapeseed obtained at 90 kg P_2O_5/ha and increased by 143.66% over control. Maximum seed yield (2196.60 kg/ha) was obtained at 120 kg N/ha along with 90 kg P_2O_5/ha and it was 377.94% increased over no nitrogen and phosphorus.

Among the nitrogen levels, 120 kg N/ha produced the highest stover yield. On the other hand 90 kg P_2O_5/ha produced the highest stover yield and the treatment combination of 120 kg N with 90 kg P_2O_5/ha produced the highest stover yield (4485.56 kg/ha).

The highest biological yield was produced from the treatment 120 kg N/ha. Among phosphorus levels, 90 kg P_2O_5/ha produced the highest biological yield ha^{-1}. The combined effect of 120 kg N with 90 kg P_2O_5/ha produced the highest biological yield ha^{-1}.

The treatment 120 kg N/ha and 90 kg P_2O_5/ha gave the highest harvest indices 32.73% and 31.96% respectively. The combination of 120 kg N with 90 kg P_2O_5/ha was found to be best for harvest index (38.47%) for the rapeseed cv. SAU Sarisha-1 in this study.

Nitrogen had no significant effect on oil content of rapeseed but affected the oil yield, but phosphorus showed differences in increasing oil content as well as oil yield. Nitrogen at the rate of 120 kg/ha gave highest oil yield (674.77 kg/ha). Phosphorus application at 90 kg P_2O_5/ha gave highest oil content (41.59%) as well as oil yield (596.18 kg/ha).

The control treatments comprises of without nitrogen, phosphorus and its combination showed significantly lowest yield components which resulted lower seed yield as well as oil as content.

From the present study it may be concluded that nitrogen and phosphorus levels influenced the plant height, yield, yield components and seed quality of rapeseed cv. SAU Sarisha-1. Among the nitrogen and phosphorus levels, 120 kg N/ha and 90 kg P_2O_5/ha were found influencing the taller plants, more number of yield components, higher seed yields and oil yield. In these context, combination of 120 kg N/ha with 90 kg P_2O_5/ha was found most suitable dose for increasing yield as well as oil content.

REFERENCES

Abadi, G. R. N., Khodabandeh, N., Aeshi, N. and Paigambari, A. (2001). Effect of nitrogen application and irrigation on yield and yield components in two rapeseed cultivars. *Indian J. Agric. Sci.* **32**(4): 765-772.

Abedin, 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. *Brassica* **5**(3/4): 35-41.

Ali, M. H. and Rahman, A. M. (1986). Response of nitrogen in TS-72 (Kalynia) cultivar of *Brassica campestris*. *Bangladesh J. Agric.* **11**(3): 85-86.

Ali, M. H. and Ullah, M. J. (1995). Effect of different levels and methods of nitrogen application on growth and yield of rapeseed (*Brassica campestris* L.) *Ann. Bangladesh Agric.* **5**(2): 115-120.

Ali, M. H., Zaman, S. M. H. and Hossain, S. M. A. (1996). Growth characters and their contribution to seed and oil yields of rapeseed Brassica campestris L. in relation to nitrogen, sulphur and population density. *J. Asiat. Soc. Bangladesh Sci.* **22**(1): 107-116.

Allen, E. J. and Morgan, D.G. (1972). A quantative analysis of growth and yield variation of oilseed rapeseed and mustard. *J. Agric. Sci., Camb.* **103**: 249-252.

Arthamwar, D. N., Shelke, V. B., Mundhe, P. R., Dhoble, M. V. and Ekshinge, B. S. (1996). Effect of nitrogen and phosphorus levels on yield and nutrient uptake by mustard. *J. Maharastra Agril. Univ.* **21**(3): 378-380.

Bardsley, C. E. and Lancster, J. D. (1965). Sulphur. In: Black, C.A. (ed) . Methods of Soil Analysis. Part 2. Chemical and Microbiological properties. 2nd ed. Agronomy No. 9. ASA. Madison, Wisconsin, USA. pp.1103.

BARI (Bangladesh Agricultural Research Institute). (1999). Annul Report. Joydebpur, Gazipur 1701, Bangladesh.

BBS (Bangladesh Bureau of Statistics). (1999). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2002). Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning, Government of Bangladesh. pp. 122-139.

BBS (Bangladesh Bureau of Statistics). (2005). Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning, Government of Bangladesh.

Bhan, S. and Singh, A. (1976). Note of the response of Mustard to N P K fertilizer in centre tract of Uttar pradesh. *Indian J. Agron.* 24(2): 180-186.

Birbal, S., Vivek, K. and Nema, M. L. (2004). Response of mustard, Brassica juncea (L.) czern and Coss to phosphorus and sulphur levels in rice lowlands. *J. Oilseeds Res.* 21(1): 181-182.

Brar, Z.S., Bal, S. D. and. Johl, A. S. (1998). Influence of sowing date & planting geometry on the performance of gobhi sarson (*Brassica napus*). *J. Agric. Sci.* 102: 23-31.

Bremner, J. M. (1965). In: Black, C.A (ed). Inorganic forms of nitrogen. Chemical and Microbiological Properties. Methods of Soil Analysis. Part 2. Monograph No. 9. ASA. Madison, Wisconsin, USA. pp. 1185.

Bremner, J. M. and Mulvaney, C. S. (1965). In: Page. A. L. (ed). Nitrogen-Toral. Methods of Soil Analysis. Chemical and Microbiological Properties. Part 2. ASA. SSSA. Madison, Wisconsin, USA. pp. 595-624.

Chapman, H. D. (1965). Cation exchange capacity. In: Black, C. A. (ed). Methods of Soil Analysis. Part 2. Monograph No. 9. ASA. SSSA. Madison, Wisconsin, USA. pp. 891-900.

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)* Biobed. **12**: 1-2.

Chaudhury, S. K., Gogulwar, N. M. and singh, A. K. (1991). Effect of nitrogen and sulphur on seed yield and oil content 'varuna' mustard (*Brassica juncea*). *Indian J. Agron.* **37**(4): 839-840.

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

Davaria, D. K. and Mehta, H. M.(1995). Effect of irrigation, nitrogen and ascorbic acid on indian mustard (*Brassica juncea*). *Indian J. Agron.* **40**(3): 522-524.

Day, P. R.1995. In: Black, C. A. (ed). Particle fractionation and particle size analysis. Methods of Soil Analysis. Part 2.Madison, Wisconsin, USA. pp. 545-567.

Donald, C. M. (1963). Competition among crop and pasture plants. *Ann. Agron.***15**: 1-18.

Dubey, O. P., Sahu, T. R. and Garg, D. C. (1994). Response and economics in relation to nitrogen and sulphur nutrition in Indian mustard (*Brassica juncea*). *Indian J. Agron.* **39**(1): 49-53.

FAO (Food and Agricultural Organization). (1999). FAO Production Year Book. Food and Agricultural Organization of the United Nations, Rome 00108 Italy. 53:115.

FAO (Food and Agricultural Organization). (2004). FAO Production Year Book. Food and Agriculture Organization of United Nations, Rome 00100, Italy. **57**: 113.

Gawai, P. P., Chaudhari, C. S., Zade, N. G. and Darange, S. O. (1994). Response of mustard to nitrogen fertilization and spacing. *J. Soils Crops.* **4**(1): 44-46.

Ghosh, A., Mondal, S. S., Sitangshu, S., Ghosh, A. and Sarker, S. (2001). Response of rapeseed to potassium, nitrogen and biofertilizer. *J. Potassium Res.* **17**(1-4): 85-88.

Gupta, B. R., Pathak, P. K. and Bhan, S. (1972). Effect of NPK on yield, nutrient uptake and quality of tori. *Indian J. Agron.* **17**: 81-91.

Gurjar, B. S. and Chauhan, D. V. S. (1997). Yield attributes and seed yield of indian mustard (*Brassica juncea*) as influenced by varieties, fertility level. *Indian J. Agron.* **42**(1): 142-144.

Hassan, A.A. and Rahman, A.(1987). Effect of various combinations of water supplies and nitrogen rates on growth and yield of mustard. *Thai. J. Agric. Sci.* **20**: 17-35.

Hossain, A. and Gaffer, M. A. (1997). Influence of nitrogen on yield of mustard. *Bangladesh J. Agric.***15**(4): 72-80.

Hughes, M. (1965). Determination of moisture and oil in the seed of winter rape (Brassica napus). Comparison of extraction methods for the estimation of oil. *J. Agric.* **20**: 745-747.

Hunter, A. H. (1984). Soil Fertility Analytical Services in Bangladesh. Bangladesh Agricultural Research Council (BARC), pp. 1-7.

Islam, N. and Mondal, M. F. (1997). Effect of nitrogen nutrition on the growth and yield of mustard and rapeseed. *Bangladesh J. Sci. Res.* **15**(1):45-52.

Jackson, M. L. (1958). Soil Chemical Analysis. Prentice-Hall Inc, EngleWood Cliffs, N. J. p. 498.

Jensen, E. S. (1990). The release and fate of nitrogen from catch-crop materials decomposing under field condition. *J. Soil Sci.* **43**(2): 335-345.

Kantwa, S.R. and Meena, N. L. (2002). Effect of irrigation, Phosphorus and PSB on growth and yield of mustard. Anna. of Agric. Res. **23**(3): 456-460.

Khaleque, M.A. (1985). A guide Book on Production of Oil crops in Bangladesh. DAE and FAO/UNDP Project BGD/79/-34. Strengthening Agricultural Extension Service, Khamarbari, Farmgate, Dhaka. p. 3.

Krogman, K. K. and Hobbs, E. H. (1975). Yield and morphological response of rape (*Brassica campestris* L. *cv. Span)* to irrigation and fertilizer treatments. *Can. J. Plant Sci.* **55**: 903-910.

Kumar, S. D. and Singh, R. D. (2003). Indian mustard (*Brassica juncea* L.) seed yield as influenced by seeding date, spacing and N levels. *J. Applied Biol.* **13** (1/2):139-146.

Khan, M. A., Singh, S., Khan, M. and Samiullah. (2003). Interactive effect of nitrogen and plant growth regulators on biomass partitioning and seed yield in mustard: mediation by ethylene. *Brassica*. **5**(3/4): 64-71.

Meena, B. S. and Sumeriya, H. K. (2003). Influence of nitrogen levels, irrigation and interculture on oil and protein content, soil moisture studies and interaction effects of mustard (*Brassica juncea* L. Czern and Coss). Crop Res. *Hisar*. **26**(3): 409-413.

Meena, B. S., Sarma, G. L. and Sharma, R. P. (2002). Effect of nitrogen, irrigation and interculture on yield attributes and yield of mustard (*Brassica juncea* L. Czern and Coss). *Res.Crops*. **3**(1): 37-39.

Mina, A.H. (2003). Response of rainfed Indian mustard (*Brassica Juncea*) to phosphorus and row spacing. *Indian J. gran*. **41**(2): 279-281.

Mina, B. L., Monoher, R. S. and chaudhary, D. R. (2003). Yield attributes, yield and quality of mustard (*Brassica juncea*) as influenced by phosphorus and zinc nutrition. Ann. Agric. Res. **24**(1): 87-90.

Mondal, M. R. I., Fattah, Q. A., Chaudhury, A. J. M. E. H., Poddar, P. and Alam, M. S. (1996). Effect of fertilization on yield and economic return of rapeseed/mustard. Dhaka Univ. *J. Biol. Sci*. **5**(2): 173-177.

Mondol, M. R. A. and Gaffer, M. A. (1983). Effect of different levels of nitrogen and phosphates on yield and yield contributing characters of mustard. *Bangladesh J. Agril. Res*. **8** (1): 37-93.

NNC. (1984). Nutrition Policy for Bangladesh. National Nutrition Council, Bangladesh. pp. 28-29.

Olsen, S. R. and Dean, L. A. (1965). Phosphorus. In: Black, C. A (ed). Methods of Soil Analysis. Monograph No. 9. ASA. Madisin, Wisconsin, USA. pp. 1035-1088.

Olsen, S. R. and Sommers, L. E. (1982). Phosphorus. In: Page, A. I (ed). Methods of Soil Analysis. Part II. Chemical and Microbiological properties. 2nd ed. Monograph No. 9.ASA. Madison, Wisconsin, USA. pp. 404-407.

Ozer, H. (2003). Sowing date and nitrogen rates effect on growth, yield and yield components of two summer rapeseed cultivars. *European J. Agron*. **19**(3): 453-463.

Patel. J.R. and Shelke, V.B. (1999). Effect of Farmyard manure, phosphorus and sulphur on growth, yield and quality of Indian mustard (*Brassica juneca*). *Indian J. Agron*. 43(4): 713-717.

Patel, J. R. (1998). Effect of irrigation and nitrogen on mustard. *J. Maharashtra Agril. Univ*. **23**(3): 254-261.

Patel, R. H., Sharma, C. V. and Usadadia, V. P. (2004). Influence of irrigation schedule, spacing and nitrogen on growth, yield and quality of mustard (*Brassica juncea* L. Czern and Coss). *Res. crops*. **5**(2/3): 290-293.

Perniona, M., Gwarini, D. and Rosco, P. (1989). Influence of timing and rate of nitrogen fertilizer application rate on rape productivity on the Ofanto Plain. *Informmatore Agrario*. **45**(32): 65-66.

Poonia, B.S., Singh, J. and Kumar, R. (2002). Effect of levels and sources of phosphorus on yield and nutrient content of mustard (*Brassica juncea* L.). *Ann. Biol.* **18**(2): 133-136.

Prasad, K., Chaudhary, H. P. and Uttam, S. K. (2003). Effect of N, P, S and Zn nutrition on nutrient uptake, quality and yield of rainfed Indian mustard. *Indian Agriculturist.* **47**(1/2): 45-50.

Pratt, P. J. (1965). Lithium, Sodium and Potassium. In: Black, C. A (ed). Methods of Soil Analysis. Part 2. Monograph No. 9. ASA. Madison, Wiscon, USA. pp. 225-246.

Ram, B., Pateck, R. G. and Ram, B. (1999). Effect of phosphorus, sulphur and PSB on growth and yield of mustard. *Agril. Sci. Digest Karnal.* **19**(3): 203-206.

Russell, O.F. (1986). MSTAT-C package programme. Crop and Soil Science Department, Michigan State University, USA.

Saha, C. S., Baral, K., Garai, A.K. and Dutta, J.K. (2003). Effect of sowing dates and nitrogen levels on some biochemical paramaters, seed yield and oil content in rapesead cv. B-9. *J. Maharasta Agril. Univ.* **28**(3): 235-237.

Saikia, U. S., Chopra, U. K, Singh, A. K. and Goswami, B. (2002). Stimulation of biomass and seed yield of Indian mustard (Brassica juncea) under different levels of nitrogen. Ann. *Agric. Res.* **23**(4): 685-691.

Saran, G. and Giri, G. (1990). Influence of nitrogen, phosphorus and sulphur on mustard under semi arid rainfed condition of North-West. *Indian J. Agron.* **35**(1-2): 131-136.

Shamsuddin, A. M., Islam, M. A. and Asaduzzaman, S. M. (1987). Effect of nitrogen on yield and yield contributing characters of mustard at different levels. *Bangladesh J. Agric. Sci.* 14(2): 165-167.

Sharawat, S., Singh, T. P., Singh, J. P. and Sharawals, S. (2002). Effect of nitrogen and sulphur on the yield and oil content of Varuna mustard (*Brassica juncea* L.). *Prog. Agric.* **2**(2): 177.

Sharma, P. P. and Jain, N. K. (2002). Nitrogen requirement on indian mustard (*Brassica juncea*) under different crop sequences. *Indian J. Agril. Sci.* **72**(2): 101-103.

Sheppard, S. C. and Bates, T. E. (1980). Yield and chemical composition of rape in response to nitrogen phosphorus and potassium. *Can. J. Soil Sci.* **60**: 153-162.

Shukla, A. and Kumar, A. (1997). Seed yield and oil content of Indian mustard (*Brassica juncea* L.) varieties as influenced by N fertilization. *J. Res. Birsa Agril. Univ.* **9**(2): 107-111.

Shukla, R. K., Kumar, A., Mahapatra, B. S. Kandpal, B., Kumar, A. and Kandpal, B. (2002 a). Integrated nutrient management practices in relation to morphological and physiological determinants of seed yield in Indian mustard (*Brassica juncea*). *Indian J. Agril. Sci.* **72**(11): 670-672.

Shukla, R. K., Kumar, A., Mahapatra, B. S., Basanth, K., Kumar, A. and Kandpal, B. (2002 b). Response of promising varieties of rapeseed (*Brassica napus*) to nitrogen and phosphorus fertilizer on the Tarai region of Uttaranchal. *Ann. Agril. Res.* **23**(4): 630-633.

Sidluaskas, G. (2000). The influence of nitrogen's role of spring oil seed rapeseed yield. *Agril. Sci. Articles.* **69**: 14-32.

Singh, A. and Meena, N. L. (2003). Effect of nitrogen and phosphorus levels on the oil and protein yield of mustard (*Brassica juncea*). *Ann. Agric. Res.* **24**(2): 368-371.

Singh, D., Jain, K. K. and Sharma, S. K. (2004). Quality and nutrient uptake in mustard as influenced by levels of nitrogen and sulphur. *J. Maharashtra Agril. Univ.* **29**(1): 87-88.

Singh, A., Singh, R.C. and Saran, G. (2003) Response of rainfed Indian mustard (*Brassica juncea*) to nitrogen. *Indian J. Agron.* 43(1): 125-129.

Singh, G. K. and Prasad, K. (2003). Studies on the effect of row spacing and nitrogen doses on the yield and profit from Indian mustard. *Progress. Agric.* **3** (1/2): 146-147.

Singh, L. N. (2004). Effect of biofertilizer with graded levels of nitrogen on lowland rice and its carryover effect on succeeding crop of rapeseed (*Brassica campestris* var. Toria). Biofertilizer technology for rice based cropping system. Pp. 181-186.

Singh, L., Saini, S. L. and Singh, R. C.(1996). Effect of row spacing and fertilizer level on late sown Indian mustard (*Brassica juncea*) ciltivars. *Indian J. Agron.* **41**(1): 166-167.

Singh, P. C. (2002). Effect of different levels of nitrogen and phosphorus on yield, yield components and oil content of mustard (*Brassica juncea* L.) cv. Varuna. *J. Living World.* **9**(1): 1-4.

Singh, R. P., Singh, Y. and Singh, Y. (1998). Performance of rainfed Indian mustard (*Brassica juncea*) varieties at varying levels of nitrogen. *Indian J. Agron.* **43**(4): 709-712.

Singh, S. and Saran, G. (1989). Effect of sulphur and nitrogen on growth, yield, quality and nutrient uptake of Indian rape. *Indian J. Agron.* **32**(4): 474-475.

Singh, S. D. and Yusuf, M. (1979). Effect of water, nitrogen and row spacing on yield and oil content of brown sarson. *Can. J. Plant Sci.* **59**: 437-442.

Singh, S. K., Singh, G. and Singh, G. (2002). Response of Indian mustard (*Brassica juncea*) varieties to nitrogen under varying sowing dates in eastern Uttar Pradesh. *Indian J. Agron.* **47**(2): 242-248.

Singh, S. M., Dahiya, D. R. and Singh, R. P. (1985). Effect of varying rectangularity's, nitrogen and varieties and yield attributes of mustard. *Indian. J. Agron.* **30**(1): 78-83.

Sinha, S., Nayak, R. L. and Mitra, B. (2003). Effect of different levels of nitrogen on the growth of rapeseed under irrigated and rainfed conditions. *Env. Ecol.* **21**(4): 741-743.

Sinsinwar, B. S., Kumar, A., Premi, O. P. and Singh, F. (2004). Production potential and nitrogen requirement of Indian mustard, *Brassica juncea* (L.) Czern and Coss in different crop sequences under brakish water. *J. Oilseed Res.* **21**(1): 175-177.

Srinivas, A. and Raju, M.S. (1997). Response of Indian mustard (*Brassica juncea* L. Czern & Cosson) to nitrogen application in red sandy loam soils of Andhra Pradesh. *PKV Res. J.* **21**(2): 235-237.

Sumeria, H.K. (2003). Response of mustard (*Brassica juncea* L.) to phosphorus, triacontanol granule and growth promoters. *Agricultural science Digest.* **23**(2): 134-136.

Tarafder, M. G. S. and Mondal, M. H. (1990). Response of mustard (var. Sonali sorisha) to nitrogen and sulphur fertilization. *Bangladesh J. Agric. Sci.* **15**(2): 125-132.

Thakuria, K. and Gogoi, P. K. (1996). Response of rainfed Indian mustard (*Brassica juncea*) to nitrogen and row spacing. *Indian J. Agron.* **41**(2): 279-281.

Tomar, R. K. S., Chouraria, S. C., Raghu, J. S. and Sing, V. B. (1996). Growth, yield and net returns of mustard under different levels of nitrogen and sulphur application on clay loam soils. *J. Oilseed Res.* **10**(1): 13-17.

Tomar, S., Tomar, S. and Singh, S. (1992). Effect of irrigation and fertility levels on growth, yield and quality of mustard (*Brassica juncea*). *Indian J. Agron.* **37**(1): 76-78.

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

Tripathi, A. K. and Tripathi, H. N. (2003). Influence of nitrogen levels on growth, yield and quality of Indian mustard (*Brassica juncea*) cultivar 'Varuna'. *Farm Sci. J.* **12**(1): 71-72.

Tuteja, S. S., Lakpale, R. and Tripathi, R. S. (1996). Effect of date of sowing, nitrogen levels and nitrogen splitting on mustard (*Brassica juncea*). *Adv.Plant Sci.* 9(1): 167-168.

Verma, S. C., Srivastava, R. K., Singh, R., Singh, S. K., Bisen, P. K. and Singh, R. (2002). Effect of varying levels of sulphur and potassium on yield and oil content of Indian mustard (*Brassica juncea* L. Czern and Coss). *Res.Crops.* 3(3): 650-652.

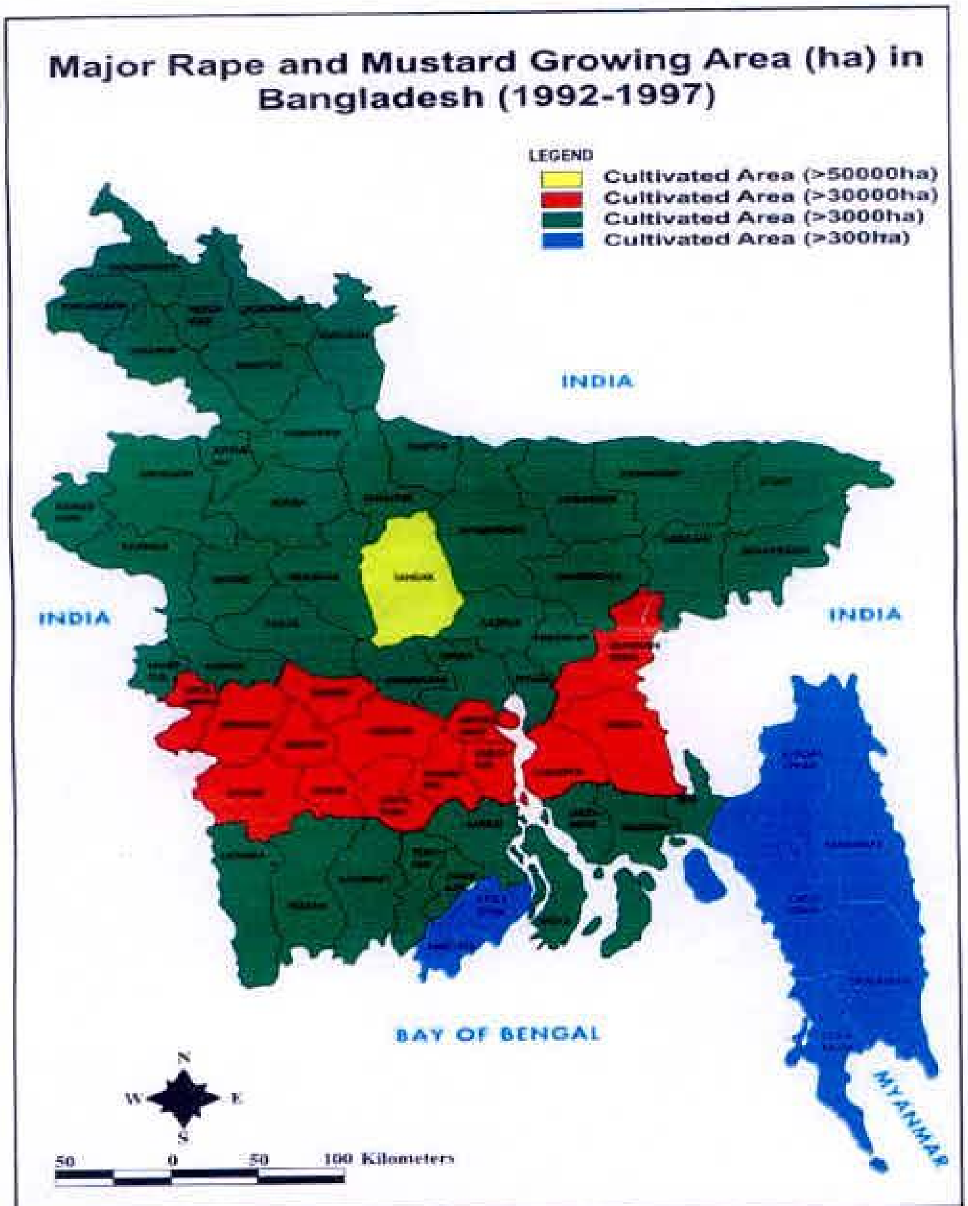
Wahhab, M. A., Mondal, M. R. I., Akbar, M. A., Ahmed, M. M. U. and Begum, M. F. (2002). Status of Oilseed Production in Bangladesh. Oilseed Research Centre. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur-1707. pp. 24-25.

Walkley, A. and Black, C. A. (1947). Chromic acid titration method for determination of soil organic matter. *Soil Sci. Soc. Am. Proc.* **63**: 257.

Zhao, F. J., Withers, P. J. A., Evans, E. J., Monaghan, S. E., Shewry, P. R. and Mogarth, S. P. (1997). Nitrogen nutrition and important factor for the quality of wheat and rapeseed. *Soil Sci. Plant Nutri.* **43**: 1137-1142.

APPENDICES

Appendix I. Major Rape and Mustard Growing Area (ha) of Bangladesh (1992-97)



Source: Status of Oil crop Production in Bangladesh, Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701.

Appendix II: Physical and chemical characteristics of initial soil (0-15 cm depth) before seed sowing

A. Physical composition of the soil

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

C. Chemical composition of the soil

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

Appendix III: Monthly average of Temperature, Relative humidity, Total Rainfall and sunshine hour of the experiment site during the period from October 2005 to February 2006

Year	Month	Air temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2005	October	30.6	24.6	27.60	77	326	142.20
	November	29.1	19.8	24.45	70	03	197.63
	December	27.1	15.7	21.4	64	Trace	217.03
2006	January	25.3	18.2	21.75	68	0	165.10
	February	31.3	19.4	25.35	61	0	171.01

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

Appendix IV. Source of variation, degree of freedom and mean square for yield attributes

Source of variation	d.f.	Mean square						
		No. of plant per m^2	Plant height (cm)	Number of branches per plant	Number of siliquae per plant	Siliqua lenght (cm)	Number of seeds per siliqua	1000-seed weight (g)
R	2	99.750	82.811	1.313	83.45	0.362	1.816	0.055
N	3	61.632 ^{NS}	148.635**	2.306^{NS}	4557.010**	1.091**	52.247**	1.555**
P	3	20.965 ^{NS}	132.031**	1.806 ^{NS}	1169.586**	1.186**	38.197**	1.760**
N x P	9	27.891 ^{NS}	58.740*	1.287 ^{NS}	184.384**	0.792**	18.580**	0.586*
Error	30	23.417	23.109	0.824	43.091	0.163	3.765	0.155
Total	47							

Note: Single and double asterisks indicates significant at 5% and 1% levels respectively. NS means non significant, R= Replication, N= Nitrogen and P=Phosphorus

Appendix V. Source of variation, degree of freedom and mean square for yield and harvest index and oil content

Source of variation	d.f.	Mean square						
		Seed yield (g/plant)	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield(kg/ha)	Harvest index (%)	Oil content (%)	Oil yield (kg/ha)
R	2	0.097	90011.648	91532.439	657.813	5.830	0.110	13033.321
N	3	12.795**	2063543.568**	12861934.009**	1654535.188**	131.432**	0.179 NS	303953.379**
P	3	3.254**	479525.38**	1364731.967**	21628895.688**	69.024**	2.382**	56463.587*
N x P	9	1.323**	248831.469*	480378.883*	655634.854**	13.091*	2854**	30518.741*
Error	30	0.238	94579.86	187787.10	624.479	5.662	0.413	13973.844
Total	47							

Note: Single and double asterisks indicates significant at 5% and 1% levels respectively. NS means non significant, R= Replication, N= Nitrogen and P=Phosphorus