EFFECT OF NITROGEN ON THE GROWTH AND YIELD PERFORMANCE OF THREE MUSTARD VARIETIES

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A Thesis
submitted to the Agrotechnology Discipline in partial fulfillment of the requirement for the degree of Master of Science in Agronomy

Agrotechnology Discipline
Khulna University
Khulna-9208
Bangladesh

August, 2008

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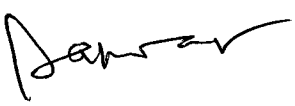

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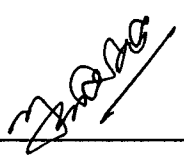

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Chairman,
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DEDICATED TO MY
BELOVED PARENTS AND GRANDMOTHER

ACKNOWLEDGEMENT

First of all, the author is very much grateful to almighty God who always helps the author for solving any difficult situation and has enabled him to complete this thesis.

The author takes profound pleasure to express his sincere gratitude to his very much beloved teacher and supervisor, Dr. Md. Sarwar Jahan, Associate Professor, Agrotechnology Discipline, Khulna University, Khulna, Bangladesh, for his cordial love, brilliant suggestions, constructive criticisms, sincere co-operations and encouragement throughout the whole period of research work and also in completing this thesis.

The author would like to extend his profound gratitude, vast appreciation and heartiest indebtedness to his cosupervisor Professor Dr. Md. Yasin Ali, Agrotechnology Discipline, Khulna University, Khulna, Bangladesh, for his generous guidance and assistance in completion of this thesis.

The author finds it a great pleasure in expressing his heartfelt indebtedness, deep sense of gratitude, sincere appreciation and profound regard to all the teachers of Agrotechnology Discipline, Khulna University, Khulna, Bangladesh, for their kindful co-operations and valuable suggestions during the study.

The author would like to express his sincere thanks to Nivanon Roy, skilled farmer, Md. Samsol Alam, Section Officer (Lab.) of Agrotechnology Discipline and Jahan Al Mahmud, Scientific Officer (RARS, Jessore) for their cooperation in the research work.

Lastly, but by no means least the author would like to convey all gratitude and love to his parents, brothers, sisters and relatives for their encouragement, blessing, moral support, prayer and sacrifices which enable him to complete this thesis with patience and perseverance.

August, 2008 The Author

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ABSTRACT

A field experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna from November, 2007 to February, 2008 to study the effect of nitrogen on the growth and yield performance of mustard. The experiment consisted of four levels of nitrogen *viz.* 0, 46.5, 93 and 139.5 kg N ha^{-1} as well as three varieties of mustard *viz.* BARI Sharisha-11, BARI Sharisha-12 and BARI Sharisha-13 as treatments. The experiment was laid out in a Randomized Complete Block Design (RCBD) with two factors. The seeds were sown @ 9 kg ha^{-1} on 06 November, 2007 by using line sowing method. Harvesting was done at physiological maturity stage. Data were collected on growth characters such as plant height, leaf number and yield contributing characters such as branch number $plant^{-1}$, siliqua length, seed number $siliqua^{-1}$, seed yield, stover yield and biological yield. BARI Sharisha-11 performed well regarding plant height (120.09 cm), leaf number (67.35), number of branches $plant^{-1}$ (17.80), total number of siliqua per plant (291.4), seed yield (2.16 t ha^{-1}), stover yield (2.04 t ha^{-1}), biological yield (4.20 t ha^{-1}), harvest index (50.84%) and 1000-seed weight (3.60 g) than other varieties. The highest number of primary branches, secondary branches, total branches $plant^{-1}$ (19.22), total siliqua $plant^{-1}$ (411.87), seed number $siliqua^{-1}$ (18.18), siliqua length (5.27 cm), 1000-seed weight (3.66 g), seed yield (2.95 t ha^{-1}), stover yield (2.62 t ha^{-1}), biological yield (5.96 t ha^{-1}) and harvest index (52.97 %) were found where nitrogen was applied @ 139.5 kg ha^{-1}. The interaction effect of nitrogen and variety was varied significantly at all parameters of growth and yield attributes except plant height and leaf number at 10 DAS and 1000-seed weight. BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} exhibited the best performances in case of most of the parameters.

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CHAPTER I

INTRODUCTION

Mustard (*Brassica* spp.) is an important edible oil crop of Bangladesh. Locally It is known as Sharisha. It tops the list in respects of area and production among the oil crops grown in the country. Mustard is being used here as a cooking oil from the time immemorial. Mustard oil plays a great role as a fat substitute in our daily diets as well as in the economy of the nation. It is widely used as a cooking ingredient, condiment. Mustard oil cakes are also used as a concentrate cattle feed and as manure (Wahhab *et al.*, 2002).

Bangladesh has been in short of 65-70 % of the demand of edible oil since long time. Our internal production can meet up only one-fourth of the requirement. As a result, a huge amount of foreign currency is being drained out every year for importing oil and oil seeds from abroad. It is, therefore, highly expected that the production of edible oil should be increased considerably to fulfill the demand. The average yield of mustard in Bangladesh is very low (0.68 t ha^{-1}) compared to that of different countries of the world (FAO, 1999). There are many reasons for lower yield and low production of mustard in Bangladesh. The major causes of low yield of mustard are majority of the farmers cultivate traditional variety and farmers grow mustard with low management practices such as without irrigation, improper use of balanced fertilizer and little use of pesticides to control insects and diseases. Seeds of high yielding varieties are not easily available to the farmers (Wahhab *et al.*, 2002).

Mustard grows in Bangladesh during Rabi season. When a large number of Rabi crops like wheat, pulses, vegetables, etc. are grown, then there is little scope of increasing area

and Gaffer, 1983; Allen and Morgan, 1972). It is thus necessary to study the performance of high yielding varieties of mustard at different nitrogen levels. This effort will certainly increase the overall productivity of mustard.

In this circumstance an attempts has been made in the present study with the following objective-

To study the performance of mustard varieties under different levels of nitrogen

CHAPTER II

REVIEW OF LITERATURE

Mustard which contributes considerably to the national economy is an important oil yielding crop in Bangladesh. But the research works done on this crop with respect to agronomic practices are insufficient. Experimental evidences from both home and abroad regarding the response of nitrogen levels on this crop are reviewed below:

Allen and Morgan (1972) found that increasing rate of nitrogen from 0-211 kg N ha^{-1} increased leaf area index, plant dry matter, siliqua dry matter, number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$ and seed yield.

Gupta and Das (1973) observed in an experiment with *Brassica campestris* (yellow sarson *cv.* 742) giving 0-100 kg N ha^{-1}, that the increasing rates of nitrogen increased seed yields.

Debowska (1973) treated winter rape (*Brassica napus*) with 60, 150 and 240 kg N ha^{-1} during three seasons and reported that seed yield increased with increasing doses of nitrogen.

Ali *et al.* (1976) noted from an experiment that nitrogen had significant effect on the yield and yield contributing characters of mustard. The maximum height of plant, number of primary branches, weight of seeds $plant^{-1}$, dry matter weight of plants and the yield of seed were obtained highest at the rate of 78.46 kg N ha^{-1}.

Agrawal and Gupta (1977) applied four levels of nitrogen *viz.* 0, 25, 50 and 75 kg ha^{-1} to *Brassica campestris var.* tori grown on a sandy loam soil under irrigated conditions and

found that seed yield increased from 1.33 t ha^{-1} with no nitrogen application to 1.8 t ha^{-1} with application of 50 kg N ha^{-1}.

Singh *et al.* (1978) reported that seed yield increased from 1.2 to 1.4 t ha^{-1} with increasing nitrogen rate from 30 kg ha^{-1} to 60 kg ha^{-1}.

Patel *et al.* (1980) performed a field experiment with mustard applied with four levels of nitrogen *viz.* 0, 25, 50 and 75 kg ha^{-1}. They reported that different levels of nitrogen gave different seed yield of mustard significantly. The highest seed yield ha^{-1} was 7.3 q achieved at the rate of 50 kg N ha^{-1} due to the formation of higher number of secondary branches $plant^{-1}$, higher number of siliqua $plant^{-1}$ and higher harvest index.

Anonymous (1982) applying four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}) to mustard under irrigated condition at Ishwardi observed that seed yield of mustard increased significantly. Increasing rate of N up to 120 kg ha^{-1} gave increasing seed yield.

Mondal and Gaffer (1983) working with mustard giving five levels of nitrogen *viz.* 0, 35, 70, 105 and 140 kg ha^{-1} observed that different levels of nitrogen had significant effects among different varieties on the plant height, number of primary branches $plant^{-1}$, number of filled siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$, weight of seed $plant^{-1}$, weight of total dry matter $plot^{-1}$ and yield of seeds. They further, observed that plant height, number of primary branches $plant^{-1}$ and number of filled siliqua $plant^{-1}$ were increased with the increasing doses of nitrogen. Nitrogen at the rate of 140 kg ha^{-1} produced the highest number of fertile seeds $siliqua^{-1}$ and seed yield (1.3 t ha^{-1}).

Tribol and Robein (1983) found in an experiment with winter rape that the application of nitrogen increased seed yields by stimulating growth of branches.

Kandil (1983) observed in an experiment with rape *cv.* Techowski that siliqua number plant^{-1}, seed weight plant^{-1} and plant height were significantly increased by nitrogen.

Results obtained by Singh and Rathi (1984) from a field experiment with mustard *cv.* varsuna grown in a sandy loam soil after green manuring with sunnhemp given 57.5 kg P_2O_5 + 22.5 kg N ha^{-1} revealed that seed yield increased linearly with increasing rates of nitrogen. Nitrogen at the rate of 160 kg ha^{-1} with a population of 62 plants m^{-2} gave the highest yield of mustard.

Narang and Singh (1985) fertilized Indian mustard with four levels of nitrogen (*viz.* 0, 50, 100 and 150 kg ha^{-1}). They observed that nitrogen at the rate of 150 kg ha^{-1} gave higher seed yields (1.8 t ha^{-1}) with a response of 8-9 kg seeds kg^{-1} of nitrogen.

Singh and Rathi (1987) recorded that increasing nitrogen rates from 0 to 80 kg ha^{-1} increased yields of toria from 0.96 to 1.16 t ha^{-1}. Yields were not further increased with 120 kg N ha^{-1}.

Singh and Singh (1987) stated that increasing rate of nitrogen from 0 to 75 kg ha^{-1} applied to mustard (*Brassica juncea*) increased the seed yield from 1.20-1.33 to 2.11-2.14 t ha^{-1}. Yields did not increase any further with 100 kg ha^{-1}.

Shamsuddin *et al.* (1987) working with mustard giving five levels of nitrogen (0, 30, 60, 90 and 120 kg N ha^{-1}) and four levels of irrigation, observed that plant height increased progressively with increasing levels of nitrogen application but was not significantly differed with the application of different levels of irrigation. Nitrogen at the rate of 120 kg ha^{-1} gave higher plant height, maximum leaf number, highest number of primary branches plant^{-1} (5.30) and the highest yield of seed (830 kg ha^{-1}). The application of

nitrogen influenced filled siliqua plant^{-1}, 1000-seed weight and harvest index significantly.

Singh and Saron (1987) set an experiment with *Brassica campestris var.* toria (*Brassica napus var.* toria) applying different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased plant height, siliqua length, number of siliqua plant^{-1} and 1000-seed weight. This dose gave seed yields of 1.20 t ha^{-1} compared to 0.89 t ha^{-1} without nitrogen. A further increase in yield with 90 kg N ha^{-1} was not significant.

Shrivastava *et al.* (1988) observed in an experiment conducted with mustard (*Brassica juncea cv.* varuna) that the application of nitrogen at the rate of 125 kg ha^{-1} at the pre-flowering stage gave the highest harvest index.

Ibrahim *et al.* (1989) carried out a field experiment with oil seed rape giving 71, 142, or 123 kg N ha^{-1} in 2 or 3 split applications at sowing or at the first, second or third irrigation. They reported that seed yields were 1.34-1.38, 1.75-1.82 and 2.03-2.16 t ha^{-1}, respectively at three nitrogen rates. The combinations including nitrogen application at the third irrigation gave the highest yield.

Murtaza and Paul (1989) studied three cultivars of rape seed *viz.* Pola, Tori-7 and Sampad grown in pots applied with four levels of nitrogen fertilizer (0, 5, 10, 20 g of urea plot^{-1}). Nitrogen had significant effect on number of primary branches plant^{-1}, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, 1000 seed weight, total plant weight, seed yield plant^{-1}, stover yield plant^{-1} and biological yield plant^{-1}. The cultivars showed significant differences in all the characters except the number of primary branches and number of siliqua plant^{-1}.

Perniola *et al.* (1989) found in an experiment conducted with winter rape *cv.* Bienvenu giving 50, 100 and 150 kg N ha^{-1} that average seed yield increased with the application of nitrogen @150 kg ha^{-1}.

Sounda *et al.* (1989) observed in two year rainfed trials with mustard (*Brassica juncea*) that increasing nitrogen rates (0-90 kg ha^{-1}) increased seed yields from 245 to 628 kg ha^{-1} in one year and also from 277 to 778 kg ha^{-1} in another year.

Tarafder and Mondal (1990) reported from an experiment conducted for determining the effect of nitrogen and sulphur on seed yield mustard (*var.* Sonali Sarisha) that seed yield increased with increasing levels of both nitrogen and sulphur. But sulphur had a critical level beyond which it contributed little to seed yield. The combination of nitrogen and sulphur fertilizers increased number of primary branches $plant^{-1}$, number of siliqua $plant^{-1}$, and number of seeds $siliqua^{-1}$ which resulted in increased seed yield. The results suggested that nitrogen at the rate of 120 kg ha^{-1} produced the seed yield in mustard in the Grey Terrace soil of Joydebpur.

Dubey and Khan (1991) working with mustard under irrigated vertisol soil observed that nitrogen at the rate of 90 kg ha^{-1} significantly increased seed yield of the mustard.

Khanpara *et al.* (1992) carried out a field experiment on clay loam soils with mustard (*Brassica juncea*) and found that the level of 60 kg ha^{-1} of nitrogen was significantly superior to other levels for seed yield, plant height and primary and secondary branches $plant^{-1}$.

Maini and Negi (1957) noticed greater plant height, more number of siliqua $plant^{-1}$ and greater number of seeds $siliqua^{-1}$ when half of the nitrogen was drilled before sowing and the rest half used as top dress in different varieties.

Gupta *et al.* (1961) observed that the use of nitrogen alone in excess caused lodging, delayed maturity and decreased oil content and increased crude protein. Sinha *et al.* (1962) and Bhatty (1964) also expressed similar views about the role of nitrogen in mustard.

Gupta and Gangasaran (1963) observed that the yield of Rai (*Brassica juncea*) increased progressively with the increase in the dose of nitrogen. They further noticed that the yield due to 50 and 100 kg N ha^{-1} was greater and thereafter decreased progressively.

Goralaski and Mereiks (1970) found that the increased rates of nitrogen (100, 200 and 250 kg N ha^{-1}) enhanced the seed yield of rape. Seed yield was higher with a single top dressing of nitrogen than with split application.

Singh *et al.* (1970) reported that application of 120 kg N ha^{-1} alone tended to give higher yield in rape than that in combination with 30 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1}. They further observed that phosphorus and potassium did not significantly influence the seed yield.

Makowski (1974) found in field trials with rape seed that 100 kg N ha^{-1} increased the seed yield from 2.97 t ha^{-1} to 3.21 t ha^{-1}. He further noticed that the highest yield was obtained by the application of N at buding stage and the yield decreased with each delay of 7 days after that stage. He concluded that N fertilization at buding stage was one of the tools for increasing and stabilizing the rape seed yield.

Sen *et al.* (1977) found that the siliqua number $plant^{-1}$, siliqua length and seed number $siliqua^{-1}$ were increased significantly by the application of increased levels of N to *Brassica juncea.* Seed yields were increased significantly from 0.65 to 1.19 t ha^{-1} by the application of 100 kg N ha^{-1}. Similar results were reported by Singh *et al.* (1978).

Gaffer and Razzaque (1983) reported that the highest level of NPK (100-80-30) produced significantly higher plant height, leaf number, more number of primary branches plant^{-1}, filled siliqua plant^{-1}, fertile seeds siliqua^{-1}, weight of seeds plant^{-1}, 1000-seed weight, seed yield plot^{-1}, dry matter weight plant^{-1} and dry matter weight plot^{-1}.

Mondal *et al.* (1996) reported that the highest seed yield of rapeseed/ mustard (1.40 t ha^{-1}) was obtained from N fertilizer level of 150 kg ha^{-1}. This level of N fertilizer was the most profitable for plant height, number of primary branches plant^{-1}, number of filled siliqua plant^{-1}, number of seeds siliqua^{-1}, siliqua length, total dry plant weight plot^{-1} and seed yield plot^{-1}.

Maini *et al.* (1996) state that the varieties were statistically different with respect to number of primary and secondary branches. The maximum number of primary and secondary branches was recorded in the Hyola-401 (5.0) and the minimum number was recorded in Semu-249/84.

Butter and Aulakh (1999) conducted a study on Indian mustard *cv.* RLM 619 and maintained three levels of nitrogen such as 50, 100 and 150 kg N. They observed that with increasing nitrogen level, number of primary and secondary branches increased.

Finlayson *et al.* (1990) carried out an experiment on rapes grown on sulphur deficient soil low in nitrogen and potassium, using (a) no fertilizer (b) 44.8 kg N ha^{-1} (c) 44.8 kg N + 22.4 kg P_2O_5 ha^{-1} (d) 44.8 kg N + 22.4 kg P_2O_5 + 205.1 kg K_2O + 89.6 kg S ha^{-1} at sowing. The yield in (d) was 2.50 t ha^{-1} compared with 2.1, 1.7 and 2.1 t ha^{-1} in (a), (b) and (c) respectively. Thousand seed weight was not affected by fertilizer treatments.

Khandkar *et al.* (1991) showed that *Brassica juncea* cv. Varuna grown at Mandsaur, Madhya Pradesh in *rabi* season applying 20, 40, 60 or 80 kg N and 0, 20, 40 or 60 kg S ha^{-1}, yield or economic return was the highest with application of 60 kg N and 60 kg S ha^{-1}.

Chowdhury *et al.* (1992) conducted a field experiment with Varuna mustard during 1988-89. The treatments comprising 4 levels of nitrogen (20, 40, 60 and 80 kg N ha^{-1}) and 3 levels of sulphur (0, 25 and 50 kg S ha^{-1}). All the yield contributing characters except 1000-seed weight were influenced significantly up to the highest level of N (80 kg ha^{-1}). Maximum seed yield was noted at the highest S level which was significantly superior to 0 and 25 kg S ha^{-1}.

Uziak and Szymanska (1979) performed an experiment in sand culture on summer rapes (*Brassica napus*), the pots were fertilized with 120, 240 and 510 mg of N from NH_4NO_3 and 2.5, 10 and 50 mg of S from K_2SO_4 singly and in combinations. They showed that increases in applied sulphur increased top growth at each installment of N and dry matter weights of above ground parts were the highest with 150 mg N and 50 mg S treatment.

Sarker *et al.* (1993) worked with four high yielding varieties of mustard viz. BAU-M/12 (Sampad), BAU-M/248 (Sambal), M-257 and SS-75 (Sonali Sarisha). They applied five levels of nitrogen *viz.* 0, 30, 60, 90 and 120 kg ha^{-1} to the crop and found that BAU-M/248 (Sambal) gave the maximum seed yield @ 120 kg N ha^{-1} and the variety Sampad followed Sambal in respect of seed yield at the same level of nitrogen. Both the varieties M-257 and SS-75 gave the maximum seed yield @ 90 kg N ha^{-1}.

Ali (1997) conducted an experiment on two varieties of mustard (Dhali and Shafal) and used four levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}). The results showed that the

varieties significantly differed in respect of number of primary branches per plant, leaf number, length of siliqua, number of mature siliqua per plant, number of mature seeds per siliqua, plant height and seed yield but 1000 seed weight was not significantly different. Both varieties produced maximum leaf number, plant height, primary and secondary branch, length of siliqua, number of mature siliqua plant^{-1}, number of mature seeds siliqua^{-1}, seed yield and 1000 seed weight at 150 kg N ha^{-1}.

Ashraf (1997) conducted an experiment with some varieties of mustard such as Sonali Sarisha and Sambal and observed that significant variation was present among the varieties in respect of all characters studied (seed yield plant^{-1}, biological yield plant^{-1}, harvest index, branches plant^{-1}, siliqua plant^{-1}, seeds siliqua^{-1}, days to maturity and days to flowering) except 1000-seed weight.

CHAPTER III

MATERIALS AND METHODS

The research work was undertaken to examine the influence of different levels of nitrogen on the performance of mustard. The materials used and the methodologies followed in this experiment are discussed below.

Location

The experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna, during the months from November 2007 to February 2008.

Experimental design and layout

The experiment was laid out in a factorial Randomized Complete Block Design (RCBD) with three replications. The size of each unit plot was 3.00 m × 2.5 m. The spaces between blocks and between plots were 50 cm and 30 cm, respectively.

Collection of seeds

The seeds of BARI Sharisha-11, BARI Sharisha-12, BARI Sharisha-13 were collected from the Regional Agricultural Research Station (RARS), Jessore, Bangladesh.

Treatment

The experiment was fertilizer and variety trial. Nitrogen was the fertilizer element. Four levels of nitrogen and three varieties were included in the study. The treatments were designated as follows:

Factor A. Variety: 3

V_1 = BARI Sharisha-11

V_2 = BARI Sharisha-12

V_3 = BARI Sharisha-13

Factor B. Fertilizer treatments: 4

N_0 = 0 kg N ha^{-1}

N_1 = 46.5 kg N ha^{-1}

N_2 = 93 kg N ha^{-1}

N_3 = 139.5 kg N ha^{-1}

Land preparation

The land was ploughed with a tractor drawn disc plough. The stubbles of the previous crop were removed. Finally, the land was leveled with ladder.

Application of fertilizer

The plots were fertilized with triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid at the rate of 160, 80, 120, 5 and 12 kg ha^{-1}, respectively (BARI, 2004). The whole of fertilizers were applied during final land preparation except urea. Half of urea was applied during final land preparation (as per experimental treatments) and rest urea was applied at the time of flowering.

Sowing of seeds

The seeds were sown on 06 November, 2007 by using line sowing method. The seed rate was 9 kg ha^{-1}.

Weeding and thinning

First weeding followed by thinning was done on 20 days after sowing (DAS). Second weeding was done on 33 DAS.

Irrigation

First irrigation was given on 20 DAS and the second irrigation was given on 45 DAS.

Application of insecticide

The plants were attacked by aphids at the later stage of growth and were successfully controlled by spraying malathion 60 EC at the rate of 2 ml L^{-1}.

Harvesting and threshing

The crop was harvested soon after plants start turning to light yellow color. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the siliquae by beating with the bamboo sticks. After separation of seeds, these were cleaned, dried and weighed. The weights of the dried stover were also taken. The weights were converted into 14% moisture level.

Collection of data

Growth characters

1. Plant height

Plant height was taken at ten days interval after the germination of seed until vegetative growth stops. The height of the plants was measured form the base to the tip of the plants

and the means were calculated.

2. Leaf number plant^{-1}

Leaf number was counted at ten days interval after the germination of seed until vegetative growth stopped. Leaf number per plant was counted from total branches of five sampled plants and then averaged.

3. Days to first flowering

Flower initiation dates were noted down by daily observation.

4. Number of branches plant^{-1}

At maturity, the number of primary and secondary as well as total branches plant^{-1} was counted from five sampled plants and then averaged.

Yield and yield attributes

5. Number of siliquae plant^{-1}

The number of siliquae per primary and secondary branches was counted from five sampled plants per plot and then average value was calculated. All the siliquae from all the five sampled plants of each unit plot were counted to determine the average number of siliquae plant^{-1}.

6. Number of seeds siliqua^{-1}

Five siliquae were randomly selected from each sampled plant of the five sampled plants of each unit plot. The capsules were split to count the seeds per siliqua.

7. Length of siliqua (cm)

Five siliquae were randomly selected from each sampled plant of the five sampled plants of each unit plot. The length of each siliqua was measured using a measuring scale and finally plot wise average capsule length was calculated.

8. 1000-seed weight (g)

One thousand oven-dried seeds were counted and then weight was recorded by means of an electric balance. Then the weight was converted to 14% moisture level.

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

Seeds obtained from whole plot basis were sun dried, cleaned and weighed carefully. Dry weight of seeds of each plot was converted to kg ha^{-1}. Seed yield was measured using a Triple Beam Balance and converted the yield into 14% moisture content by using the following formula-

$$\text{Yield (at 14\% moisture content)} = \frac{10\,(100\text{-FMC})}{(100\text{-}14)} \times \frac{\text{Plot yield (g)}}{\text{Plot area } (m^2)}$$

FMC = Field moisture content.

10. Stover yield (t ha^{-1})

Per plot stover yield was measured and converted into per hectare stover yield at 14% moisture level.

11. Biological yield (t ha^{-1})

Per plot biological yield was calculated by adding seed yield and stover yield and then it was converted into ton per hectare.

12. Harvest index (%)

Harvest index (HI), the ratio of economic (seed) yield to biological yield was estimated and expressed as percentage using the following formula.

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

Biological yield = Seed yield + Stover yield

Data Analysis

Data on plant characters, yield and yield attributes were subjected to analysis of variance (ANOVA). All the recorded data were analyzed with the computer package MSTAT-C program and differences among treatment means were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Functional relationships between yield parameters and plant growth characters were determined using simple regression analysis.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of nitrogen levels on growth and yield performance of mustard. Results obtained from the study have been presented and discussed in the following headings.

Varietal Differences

Growth characters

Plant height

Plant height differed significantly among the tested mustard varieties. Plant height of the mustard varieties ranged from 2.25 to 2.55, 3.36 to 5.05, 27.75 to 53.85, 63.13 to 86.68, 93.14 to 119.01 and 94.40 to 120.09 cm at 10, 20, 30, 40, 50 and 60 DAS respectively. The tallest plant was found in the variety BARI Sharish-11 (120.09 cm) at final day of data collection which differed significantly from other varieties (Table 1) and the lowest plant height (94.4) was found in BARI Sharisha-13 at 10 DAS. The variable effect of variety on plant height was found by Ali (1997) and Ali *et al.* (1976).

Table 1. Varietal differences in plant height of mustard

Variety	Plant height (cm) over time					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
BARI Sharisha-11	2.25	3.36b	30.51b	85.76a	119.01a	120.09a
BARI Sharisha-12	2.55	5.05a	53.85a	86.68a	99.05b	100.03b
BARI Sharisha-13	2.27	3.87b	27.75b	63.13b	93.14c	94.40c
Level of significance	NS	0.01	0.01	0.01	0.01	0.01
CV (%)	9.60	9.92	6.02	2.67	2.06	2.46

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly; NS = Non significant; DAS = Days after sowing.

Leaf number plant^{-1}

Leaf number differed significantly over time among the mustard varieties. Leaf number increased as growth proceeded. Leaf number of the mustard varieties ranged from 3.33 to 3.68, 3.61 to 7.01, 8.71 to 9.62, 14.25 to 27.95, 32.42 to 59.98 and 38.82 to 67.35 cm at 10, 20, 30, 40, 50 and 60 DAS respectively. At 10, 20 and 30 DAS, BARI Sharisha-12 produced the maximum leaf number of 3.68, 7.01 and 9.62, respectively while at 40, 50 and 60 DAS, BARI Sharisha-11 produced the maximum leaf number of 27.95, 59.98 and 67.35, respectively. BARI Sharisha-13 (Table 2) produced lower number of leaves plant^{-1}. This result is support by Ali (1997).

Table 2. Varietal differences in leaf number plant^{-1} of mustard

Variety	Leaf number over time					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
BARI Sharisha-11	3.667a	6.91ab	8.71b	27.95a	59.98a	67.35a
BARI Sharisha-12	3.683a	7.01a	9.62a	17.18b	47.95b	53.70b
BARI Sharisha-13	3.333b	6.61b	9.06ab	14.25c	32.41c	38.81c
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.02	2.73	4.17	4.74	2.99	2.00

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly; DAS = Days after sowing.

Branches plant^{-1}

The maximum number of primary branches per plant (5.33) was recorded from BARI Sharisha-12 which was statistically similar to branches obtained from BARI Sharisha-11 (Table 3). BARI Sharisha-13 produced the lowest number of primary branches per plant (3.38). The highest number of secondary branches (12.88) was found in BARI Sharisha-11 and the lowest number (4.10) was in BARI Sharisha-13. Total number of branches per plant varied significantly across varieties and ranged from 7.48 to 17.80 (Table 3). The highest number of branches per plant was recorded from the variety BARI Sharisha-11

(17.80) and the lowest was found in BARI Sharisha-13 (7.48). Similar result was also obtained by Ashraf (1997) and Ali (1997).

Table 3. Varietal differences in the branch number of mustard

Variety	Branch number plant^{-1}		
	Primary	Secondary	Total
BARI Sharisha-11	4.91a	12.88a	17.80a
BARI Sharisha-12	5.33a	7.63b	12.97b
BARI Sharisha-13	3.38b	4.10c	7.48c
Level of significance	0.01	0.01	0.01
CV (%)	5.77	7.04	4.65

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

Days to flowering

Mustard varieties needed significantly different period of time to initiate flower. BARI Sharisha-12 required the minimum days (27.33 days) for initiation of flower and BARI Sharisha-11 took the maximum period (30.08 days) to initiate flower. However, BARI Sharisha-11 and BARI Sharisha-13 did not differ significantly (Table 4) regarding flowering period. These results are supported by Ashraf (1997).

Table 4. Varietal differences in the first flowering date of mustard

Variety	Days to flowering
BARI Sharisha-11	30.08a
BARI Sharisha-12	27.33b
BARI Sharisha-13	28.91a
Level of significance	0.01
CV (%)	2.90

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

Yield and yield attributes

Siliqua plant^{-1}

BARI Sharisha-11 produced the highest number of siliqua per primary (137.00) and secondary branches (128.93) per plant followed by BARI Sharisha-12. The lowest number of siliqua in primary (41.04) and secondary (78.56) branches were recorded from BARI Sharisha-13 (Table 5).

The maximum number of mature siliqua per plant (291.38) was found in BARI Sharisha-11 followed by BARI Sharisha-12 (262.07). The lowest number (153.58) was recorded from BARI Sharisha-13 (Table 5). These results were given by Ali (1997) and Murtaza and Paul (1989).

Seed number siliqua^{-1}

The effect of variety on seed number per siliqua was significant which ranged from 10.59 to 18.64 (Table 5). BARI Sharisha-13 produced the highest number of seed per siliqua (18.64) which differed significantly from seeds produced by other varieties. The lowest number (10.59) was found in BARI Sharisha-11. Similar results were given by Ali (1997) and Ashraf (1997).

Siliqua length

Siliqua length differed significantly among the tested mustard varieties. Siliqua length ranged from 3.49 to 5.59 cm (Table 5). The highest length of siliqua (5.59 cm) was obtained from BARI Sharisha-13. BARI Sharisha-11 produced the shortest (3.49 cm) siliqua. Similar results were found by Ali (1997).

1000-seed weight

Weight of 1000-seed varied significantly and ranged from 2.77 to 3.60 g. BARI Sharisha-11 got the maximum weight of 1000-seeds (3.60 g) and the minimum was found in BARI Sharisha-12 (2.77 g) (Table 5). The higher 1000-seed weight might be due to larger size of the seed. The variable weight of 1000-seed in different mustard varieties was also reported by Murtaza and Paul (1989).

Seed yield

Seed yield of the tested mustard varieties varied from 1.61 to 2.16 t ha^{-1}. BARI Sharisha-11 produced the highest yield (2.16 t ha^{-1}) which was significantly different from other two varieties (Table 5). The variable seed yield of different mustard varieties were also reported by Ali (1997), Ashraf (1997), Sarker *et al.* (1993) and Murtaza and Paul (1989). The higher seed yield found in BARI Sarisha-11 might be due to more number of branches per plant, higher number of siliqua per plant, larger seed size, and higher harvest index (Table 5).

Stover yield

Stover yield showed the similar trend likes as seed yield. The variety BARI Sharisha-11 showed the maximum weight of stover (2.04 t ha^{-1}) followed by BARI Sharisha-12 (1.80 t ha^{-1}). The lowest weight (1.58 t ha^{-1}) was recorded in the BARI Sharisha-13 (Table 5). These results were supported by Murtaza and Paul (1989).

Table 5. Varietal differences in the yield and yield attributes of mustard

Variety	Siliqua number plant^{-1}			Number of seed per siliqua	Siliqua length (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
	Primary branch	Secondary branch	Total							
BARI Sharisha-11	137.00a	128.93a	291.38a	10.59c	3.49c	3.60a	2.16a	2.04a	4.20a	50.84a
BARI Sharisha-12	124.47b	106.56b	262.07b	14.58b	4.24b	2.77c	1.90b	1.80b	3.70b	50.47ab
BARI Sharisha-13	41.04c	78.56c	153.58c	18.64a	5.59a	3.41b	1.61c	1.58c	3.20c	49.84b
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	3.05	2.46	1.42	5.58	3.11	1.85	2.20	2.75	2.29	0.77

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

Biological yield

Biological yield of the tested mustard varieties varied significantly and ranged from 3.20 to 4.20 t ha^{-1} (Table 5). BARI Sharisha-11 produced the highest biological yield (4.20 t ha^{-1}) and the lowest was found in BARI Sharisha-13 (3.20 t ha^{-1}). The variable biological yield of different mustard varieties were also reported by Murtaza and Paul (1989) and Ashraf (1997).

Harvest index (%)

Harvest index of the tested mustard varieties ranged from 49.84 to 50.84%. BARI Sharisha-11 had the highest harvest index (50.84%) which was statistically similar with BARI Sharisha-12 (Table 5). BARI Sharisha-13 had the lowest harvest index (49.84%). The variable harvest index of different mustard varieties were also reported by Ashraf (1997).

Effect of nitrogen

Growth characters

Plant height

Plant height was recorded at ten days intervals. Plant height increased with increasing doses of nitrogen. In all the sampling dates, plants receiving the highest dose of N (139.5 kg ha^{-1}) produced the taller plants which were significantly different from plant height obtained from other treatments except at 20 DAS (Table 6). The shortest plants in all the sampling dates were resulted from control treatments. Treatments N_1 and N_2 showed similar height of plant at 10 and 20 DAS but at the rest of the growing period they exerted dissimilar influence (Table 6). Almost similar results were also reported by many researchers Ali *et al.* (1976); Gaffer and Razzaque (1983); Mondal and Gaffer (1983); Mondal *et al.* (1996) and Shamsuddin *et al.* (1987). Overviews of the effect of different doses of N on three mustard varieties have shown in plate 1 to plate 12.

Leaf number

Leaf number differed significantly over time among the mustard varieties. Leaf number increased with increasing days. Leaf number of the mustard varieties ranged from 2.97 to 4.02, 6.07 to 7.63, 6.87 to 11.69, 11.33 to 28.02, 20.60 to 77.09 and 25.56 to 85.16 at 10, 20, 30, 40, 50 and 60 DAS, respectively. At all growth stages, 139.5 kg N ha^{-1} produced the maximum leaf number whereas control treatment (N_0) produced the minimum leaf number (Table 7). Different varieties have different leaf numbers and maximum leaf number is found in the highest doses of nitrogen. This result is supported by Shamsuddin *et al.* (1987).

Table 6. Effect of nitrogen on the plant height of mustard

N levels	Plant height (cm) over time					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0	1.68c	3.18c	22.12d	61.13d	85.38d	86.40d
N_1	2.17b	3.77bc	32.28c	72.05c	95.41c	96.87c
N_2	2.53b	4.43ab	42.54b	86.05b	113.26b	114.41b
N_3	3.05a	4.98a	52.54a	94.86a	120.88a	121.67a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	9.60	9.92	6.02	2.67	2.06	2.46

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly.

N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1}, N_3 = 139.5 kg N ha^{-1}, DAS = Days after sowing.

Table 7. Effect of nitrogen on the leaf number $plant^{-1}$ of mustard

N levels	Leaf number $plant^{-1}$ over time					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0	2.97c	6.07d	6.87d	11.33d	20.60d	25.55d
N_1	3.46b	6.56c	7.88c	17.86c	35.48c	41.73c
N_2	3.77a	7.12b	10.08b	21.95b	53.95b	60.71b
N_3	4.02a	7.63a	11.68a	28.02a	77.08a	85.15a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.02	2.73	4.17	4.74	2.99	2.00

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1}, N_3 = 139.5 kg N ha^{-1}, DAS = Days after sowing.

Branches $plant^{-1}$

Primary and secondary branches $plant^{-1}$ were recorded. The maximum number of primary branches per plant (6.02) was recorded when N was applied @ 139.5 kg ha^{-1}

followed by primary branches obtained from 93 kg N ha^{-1}. The lowest number of primary branches per plant (3.00) was obtained from the control plots. Gaffer and Razzaque (1983), Mondal and Gaffer (1983), Ali *et al.* (1976) and Shamsuddin *et al.* (1987) also got similar results in mustard. The highest number of secondary branches (13.20) was found in 139.5 kg N ha^{-1} and the lowest number (3.88) was in control. The maximum number of total branches per plant (19.22) was recorded when N was applied @ 139.5 kg ha^{-1}. The lowest number of branches per plant (6.88) was obtained from the control plots (Table 8). Total branches $plant^{-1}$ showed a positive and linear relationship with nitrogen dose (Fig. 1). The higher value (R^2= 0.99) suggests that over 99% of the variation in total branches $plant^{-1}$ could be explained by the variation in nitrogen dose.

Table 8. Effect of nitrogen on the branch number of mustard

N levels	Branch number $plant^{-1}$		
	Primary	Secondary	Total
N_0	3.00d	3.88d	6.88d
N_1	3.93c	6.53c	10.47c
N_2	5.22b	9.20b	14.42b
N_3	6.02a	13.20a	19.22a
Level of significance	0.01	0.01	0.01
CV (%)	5.77	7.04	4.65

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1}, N_3 = 139.5 kg N ha^{-1}

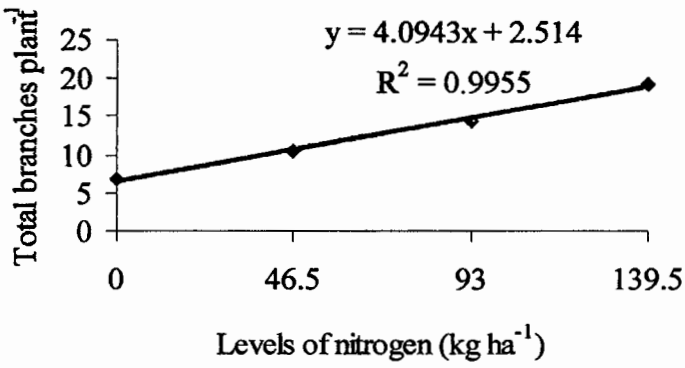

Fig. 1. Functional relationship between different levels of nitrogen and total branches per plant in mustard

Days to flowering

Nitrogen doses significantly influenced the period to initiate flower in mustard varieties. Flowering started quickly with the increasing doses of nitrogen and delayed with the decreasing nitrogen level. Nitrogen dose 139.5 kg ha^{-1} took minimum days (26.33 days) for initiation of flower; on the other hand, maximum days (31.22 days) required in control. In flowering date, control and 46.5 kg N ha^{-1} did not differ significantly and the results found in 93 and 136.5 kg N ha^{-1} also did not differ significantly (Table 9).

Table 9. Effect of nitrogen on the initiation of flowering in mustard

N levels	Days to flowering
N_0	31.22a
N_1	29.88a
N_2	27.66b
N_3	26.33b
Level of significance	0.01
CV (%)	2.90

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1}, N_3 = 139.5 kg N ha^{-1}

Yield and yield attributes

Siliqua plant^{-1}

Nitrogen levels had significant effect on siliqua production. The maximum number of mature siliqua per primary (166.23) and secondary (219.59) branches was recorded from the plot receiving the highest dose of nitrogen (139.5 kg ha^{-1}). The lowest number was recorded from the control plots (Table 10).

Plots receiving the highest dose of nitrogen (139.5 kg ha^{-1}) also produced the maximum number of mature siliqua per plant (411.47) which was statistically dissimilar from siliqua produced by other nitrogen doses. The lowest number (97.41) of siliqua plant^{-1} was recorded from the control plots (Table 10). Almost similar results were found by Tarafder and Mondal (1990); Mondal and Gaffer (1983); Kandil (1983) and Patel *et al.* (1980).

Seed number siliqua^{-1}

The effect of nitrogen on seed number per siliqua was significant which ranged from 10.33 to 18.18 (Table 10). The highest number of seeds per siliqua (18.18) was produced by the application of 139.5 kg N ha^{-1} which differed significantly from other treatments. The lowest (10.33) value was found where nitrogen was not applied. Similar results were found by Allen and Morgan (1972); Murtaza and Paul (1989) and Sen *et al.* (1977).

Siliqua length

The application of nitrogen markedly influenced the siliqua length. Siliqua length ranged from 3.48 to 5.27 cm (Table 10). The longest siliqua (5.27 cm) was obtained from the plot receiving the highest dose of N (139.5 kg ha^{-1}). Plants receiving no nitrogen

produced the shortest siliqua (3.48 cm). This result is supported by Singh and Saron (1987).

1000-seed weight

The weight of 1000-seed ranged from 2.95 to 3.66 g (Table 10). The highest 1000-seed weight (3.66 g) came from where 139.5 kg N ha^{-1} was applied. The results showed that increasing rate of nitrogen increased weight of 1000-seed gradually. Thousand seed weight also showed a positive and linear relationship with nitrogen dose (Fig. 2). The maximum value ($R^2 = 0.96$) indicates that 96% of the variation in thousand seed weight could be defined by the variation in nitrogen dose. The result is supported by Singh and Saron (1987) and Shamsuddin *et al.* (1987).

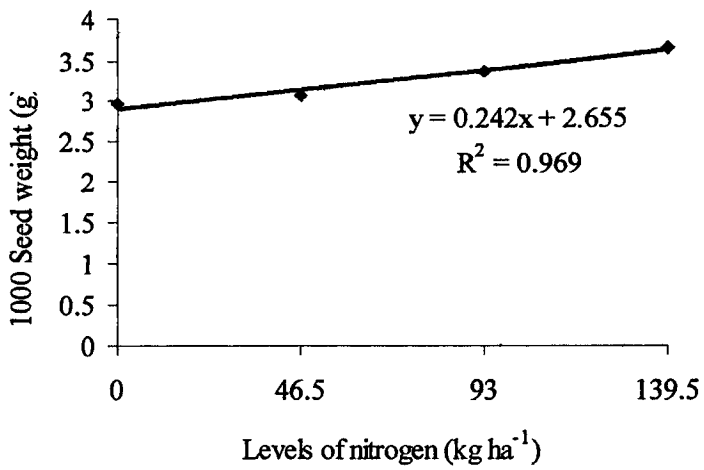

Fig. 2. Functional relationship between different levels of nitrogen and 1000 seed weight

Seed yield

Seed yield varied significantly due to nitrogen levels. It was observed that seed yield ranged from 0.99 to 2.95 t ha^{-1} (Table 10). The highest seed yield (2.95 t ha^{-1}) was obtained from the plots receiving the highest dose of nitrogen (139.5 kg ha^{-1}) and the

lowest (0.99 t ha^{-1}) was found in the control treatment. Higher doses of nitrogen increases leaf area index (LAI), leaf area duration, and crop photosynthetic rate, and leads to higher radiation interception and higher ra diation use efficiency (Girardin *et al.*, 1987; Uhart and Andrade, 1995). So, increasing doses of nitrogen increases seed yield up to a certain limit. The results showed that seed yield increased with the ascending rate of nitrogen fertilizer. Seed yield showed a positive and linear relationship with nitrogen dose (Fig. 3). This relationship showed that seed yield was dependent on nitrogen dose and over 95 % of the variation in yield could be defined from the variation in nitrogen dose. Similar results were observed by Shamsuddin *et al.* (1987); Narang and Singh (1985); Singh and Rathi (1987); Perniola *et al.* (1989); Tarafder and Mondal (1990) and Debowska (1973).

Table 10. Effect of nitrogen on the yield and yield attributes of mustard

N levels	Siliqua number plant^{-1}			Number of seed per siliqua	Siliqua length (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
	Primary branch	Secondary branch	Total							
N_0	39.21d	31.36d	97.41d	10.33d	3.48d	2.95d	0.99d	1.07d	2.07d	47.99d
N_1	74.35c	60.16c	163.70c	12.80c	3.90c	3.07c	1.27c	1.31c	2.59c	49.20c
N_2	123.55b	107.63b	269.73b	15.76b	4.83b	3.36b	2.35b	2.22b	4.58c	51.37b
N_3	166.23a	219.58a	411.87a	18.18a	5.27a	3.66a	2.95a	2.62a	5.57a	52.97a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	3.05	2.46	1.42	5.58	3.11	1.85	2.20	2.75	2.29	0.77

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1}, N_3 = 139.5 kg N ha^{-1}

Stover yield

Application of N fertilizer showed positive influence in stover yield of mustard. The plots receiving the highest dose of nitrogen (139.5 kg ha^{-1}) produced the maximum weight of stover (2.62 t ha^{-1}). It might be due to tremendous effect of N on vegetative growth specially the plant height and number of branches $plant^{-1}$ which contributed the highest production of stover yield ha^{-1}. The lowest weight (1.076) was recorded from the control plots (Table 10). Stover yield showed a positive and linear relationship with nitrogen dose (Fig. 4). Simple linear regression showed that stover yield was dependent on nitrogen dose. From fig. 4 it can also be concluded that stover yield increased with the increase of nitrogen dose. The result is supported by Murtaza and Paul (1989).

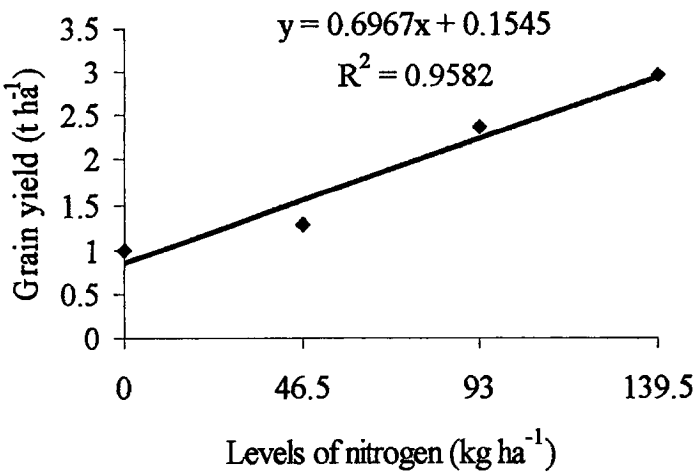

Fig. 3. Functional relationship between different levels of nitrogen and grain yield in mustard

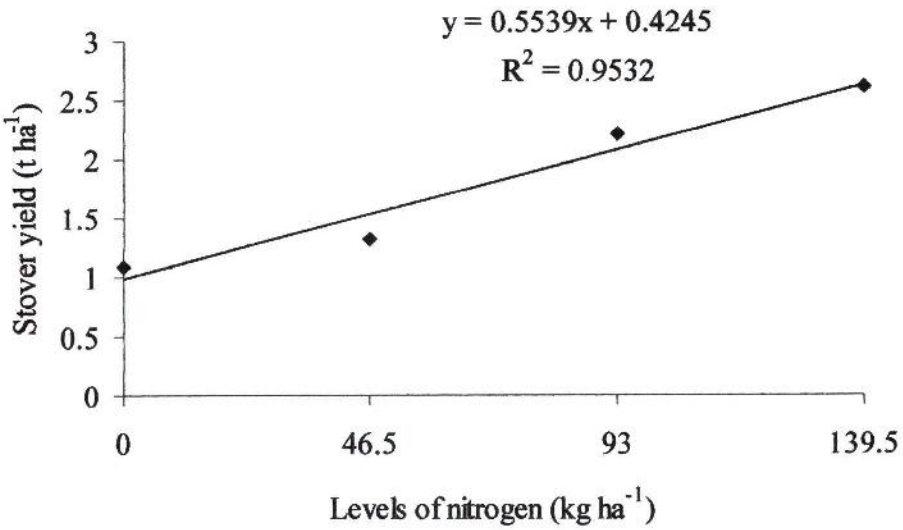

Fig. 4. Functional relationship between different levels of nitrogen and stover yield in mustard

Biological yield

The effect of nitrogen on biological yield was significant which ranged from 2.07 to 5.57 t ha^{-1} (Table 10). The N rate 139.5 kg ha^{-1} produced the highest biological yield (5.57 t ha^{-1}) which differed significantly from other treatments. The lowest (2.07 t ha^{-1}) biological yield found where nitrogen was not applied. Positive and linear relationship was also obtained when biological yield was plotted against nitrogen doses and at least 95% of the variation in biological yield could be explained by the variation in nitrogen dose (Fig. 5). Similar results were observed by Murtaza and Paul (1989).

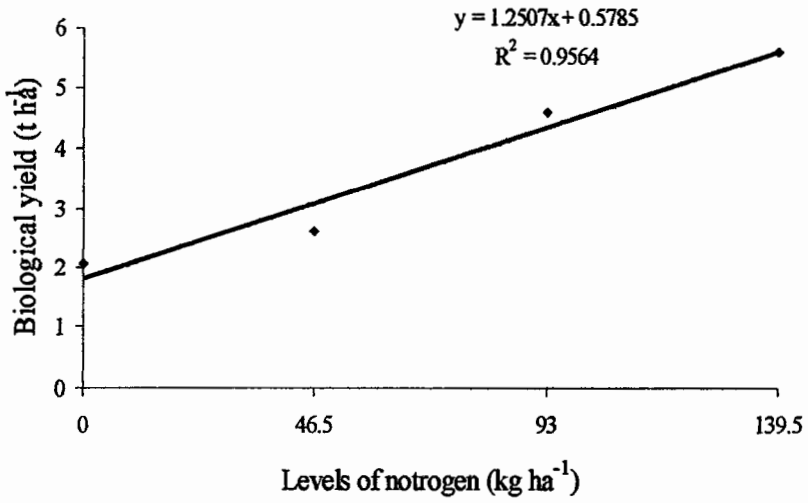

Fig. 5. Functional relationship between different levels of nitrogen and biological yield in mustard

Harvest index (%)

Results presented in Table 10 showed that 139.5 kg N ha^{-1} produced the highest harvest index (52.97%). The lowest harvest index (47.99%) was found in the control treatment. Harvest index showed a positive and linear relationship with nitrogen dose (Fig. 6). The higher value (R^2= 0.99) suggests that over 99% of the variation in harvest index could be explained by the variation in nitrogen dose. The result is supported by Shamsuddin *et al.* (1987).

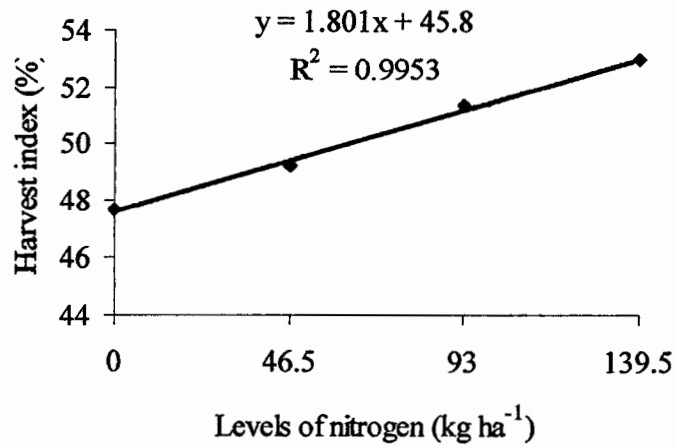

Fig. 6. Functional relationship between different levels of nitrogen and harvest index

Interaction effect of variety and nitrogen

Growth characters

Plant height

Interaction effect of nitrogen and variety on plant height was significant except at the first sampling. Plant height ranged from 2.83 cm to 6.56 cm, 13.26 to 65.66 cm, 43.4 to 102.53 cm, 67.36 to 132.53 cm and 68.4 to 133.8 cm at 20, 30, 40, 50 and 60 DAS, respectively (Table 11). The tallest plants at 20, 30 and 40 DAS were 6.56, 65.66, 102.53 cm, respectively produced by BARI Sharisha-12 fertilized with 139.5 kg N ha^{-1}. But at 50 DAS and 60 DAS, the plant height was 132.53 cm and 133.80 cm were found from BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1}. The shortest plants (2.83 cm) were recorded in BARI Sharisha-11 with control at 20 DAS. The variable effect of variety on plant height was found by Ali (1997) and Ali *et al.* (1976).

Leaf number

Leaf number $plant^{-1}$ was significantly influenced by the interaction between nitrogen and variety at all growth stages except at 10 DAS. At 20 and 30 DAS, the maximum leaf numbers of 8.06 and 12.4 were found in BARI Sharisha-12 fertilized with 139.5 kg N ha^{-1}. However, At 40, 50 and 60 DAS, BARI Sharisha-11 when fertilized with 139.5 kg N ha^{-1} produced the maximum leaf number. The lowest leaf number of 5.86, 15.66 and 20.77 were found in BARI Sharisha-13 fertilized with 0 kg N ha^{-1} at 20, 50 and 60 DAS respectively. On the other hand, the lowest leaf numbers of 6.5 and 8.73 was obtained in BARI Sharisha-12 with no nitrogen at 30 and 40 DAS, respectively (Table 12). This result is support by Ali (1997) and Gaffer and Razzaque (1983).

Table 11. Interaction effect of variety and nitrogen on the plant height of mustard

Nitrogen x Variety	Plant height (cm) over time					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
$V_1 N_0$	1.56	2.83f	16.16g	73.26f	108.26d	109.06f
$V_1 N_1$	2.16	3.20ef	22.13f	81.70e	113.93c	115.20cd
$V_1 N_2$	2.50	3.53def	34.00e	90.26d	121.33b	122.30b
$V_1 N_3$	2.80	3.90cde	49.76c	97.83b	132.53a	133.80a
$V_2 N_0$	1.80	3.46def	36.93e	66.73g	80.53f	81.73h
$V_2 N_1$	2.30	4.50c	52.30c	83.56e	91.76e	93.13g
$V_2 N_2$	2.60	5.66b	60.50b	93.90c	109.66d	110.66def
$V_2 N_3$	3.53	6.56a	65.66a	102.53a	114.26c	114.60cde
$V_3 N_0$	1.70	3.26ef	13.26g	43.40i	67.36g	68.40i
$V_3 N_1$	2.06	3.63de	22.43f	50.90h	80.53f	82.30h
$V_3 N_2$	2.50	4.10cd	33.13e	74.00f	108.80d	110.26ef
$V_3 N_3$	2.83	4.50c	42.20d	84.23e	115.86c	116.63c
Level of significance	NS	0.01	0.01	0.01	0.01	0.01
CV (%)	9.60	9.92	6.02	2.67	2.06	2.46

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

$N_0 = 0$ kg N ha^{-1}, $N_1 = 46.5$ kg N ha^{-1}, $N_2 = 93$ kg N ha^{-1}, $N_3 = 139.5$ kg N ha^{-1}

V_1 = BARI Sharisha-11, V_2 = BARI Sharisha-12, V_3 = BARI Sharisha-13

NS = Non significant, DAS = Days after sowing.

Table 12. Interaction effect of variety and nitrogen on the leaf number of mustard

Nitrogen x Variety	Leaf number over time					
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
V1 N0	3.06	6.30ef	7.13efg	16.33e	27.46i	31.80j
V1 N1	3.66	6.83cd	7.73e	26.13c	44.60f	52.13f
V1 N2	3.86	7.13bc	8.46d	31.46b	63.26c	72.06c
V1 N3	4.06	7.40b	11.53b	37.86a	104.60a	113.40a
V2 N0	3.13	6.06fg	6.50g	8.73h	18.66j	24.13k
V2 N1	3.66	6.53de	8.40d	14.60f	35.26h	39.33h
V2 N2	3.86	7.40b	11.20bc	19.86d	69.26d	65.26d
V2 N3	4.06	8.06a	12.40a	25.53c	78.66b	86.06b
V3 N0	2.73	5.86g	7.00fg	8.93h	15.66k	20.73l
V3 N1	3.06	6.33ef	7.53ef	12.86g	26.66i	33.73i
V3 N2	3.60	6.83cd	10.60c	14.53f	39.33g	44.80g
V3 N3	3.93	7.43b	11.13bc	20.66d	48.00e	56.00e
Level of significance	NS	0.01	0.01	0.01	0.01	0.01
CV (%)	5.02	2.73	4.17	4.74	2.99	2.00

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1}, N_3 = 139.5 kg N ha^{-1}

V_1 = BARI Sharisha-11, V_2 = BARI Sharisha-12, V_3 = BARI Sharisha-13

NS = Non significant, DAS = Days after sowing.

Branches $plant^{-1}$

Interaction effect of nitrogen and variety on branch production was significant. The maximum number of primary branches per plant (6.86) was recorded from the BARI Sharisha-12 fertilized with 139.5 kg N ha^{-1} and the lowest number (1.86) was obtained from the BARI Sharisha-12 in absence of N. The highest number of secondary branches (19.46) was found in BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} and the lowest number (2.00)

was in BARI Sharisha-13 fertilized with 46.5 kg N ha^{-1}. Total number of branches per plant was also found significant. BARI Sharisha-11 when fertilized with 139.5 kg N ha^{-1} and BARI Sharisha-13 fertilized with control produced maximum and minimum number of total branches which were recorded as 25.53 and 3.26, respectively (Table 13). Gaffer and Razzaque (1983), Mondal and Gaffer (1983), Ali *et al.* (1976) and Shamsuddin *et al.* (1987) also got similar results in mustard.

Table 13. Interaction effect of variety and nitrogen on the branch number of mustard

Nitrogen x Variety	Branch number per plant		
	Primary	Secondary	Total
$V_1 N_0$	3.53e	6.20e	9.73g
$V_1 N_1$	4.53d	11.40c	15.93d
$V_1 N_2$	5.53c	14.46b	20.00b
$V_1 N_3$	6.06b	19.46a	25.53a
$V_2 N_0$	3.60e	4.06f	7.66h
$V_2 N_1$	4.60d	6.20e	10.80f
$V_2 N_2$	6.26b	9.06d	15.33d
$V_2 N_3$	6.86a	11.20c	18.07c
$V_3 N_0$	1.86g	1.40g	3.26j
$V_3 N_1$	2.66f	2.00g	4.66i
$V_3 N_2$	3.86e	4.06f	7.93h
$V_3 N_3$	5.13c	8.93d	14.07e
Level of significance	0.05	0.01	0.01
CV (%)	5.77	7.04	4.65

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

$N_0 = 0$ kg N ha^{-1}, $N_1 = 46.5$ kg N ha^{-1}, $N_2 = 93$ kg N ha^{-1}, $N_3 = 139.5$ kg N ha^{-1}

V_1 = BARI Sharisha-11, V_2 = BARI Sharisha-12, V_3 = BARI Sharisha-13

Plotting seed yield against total branches $plant^{-1}$ yielded a straight line. The higher value of R^2 revealed that more than 72% of the variation in grain yield could be explained by the

variation in total branches plant^{-1} (Fig. 7).

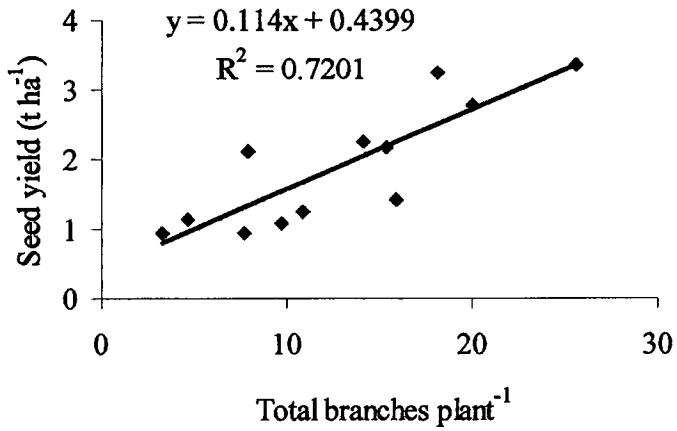

Fig. 7. Functional relationship between total number of branches per plant and seed yield in mustard

Yield and yield attributes

Siliqua plant^{-1}

Interaction effect of nitrogen and variety on total siliqua number, siliqua per primary and secondary branches showed significant effect. BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} produced the highest number of siliqua per primary branches (222.26), secondary branches (242.53) and also total siliqua plant^{-1} (495.06) where as, BARI Sharisha-13 with no nitrogen produced the lowest values (Table 14). Similar results were found by Tarafder and Mondal (1990); Mondal and Gaffer (1983); Kandil (1983) and Patel *et al.* (1980).

Seeds siliqua^{-1}

BARI Sharisha-13 fertilized with 139.5 kg N ha^{-1} produced the highest number of seeds per siliqua (24.46) (Table 14). The lowest number of seeds per siliqua (9.00) was found in BARI Sharisha-11 fertilized with 0 kg N ha^{-1} which was followed by BARI Sharisha-11 fertilized with 46.5 kg N ha^{-1} and BARI Sharisha-12 fertilized with no nitrogen. Similar results were found by Allen and Morgan (1972); Singh and Saron (1987) and Sen *et al.* (1977).

Siliqua length

Interaction effect of nitrogen and variety on siliqua length was significant. However, the longest siliqua (6.50 cm) was obtained from BARI Sharisha-13 fertilized with 139.5 kg N ha^{-1} (Table 14). The shortest siliqua (2.7 cm) was recorded from BARI Sharisha-11 receiving no nitrogen. This result is supported by Singh and Saron (1987).

1000-seed weight

BARI Sharisha-12 fertilized with 139.5 kg N ha^{-1} showed the highest 1000-seed weight (3.9 g). The lowest 1000-seed weight (2.46 g) was recorded from BARI Sharisha-12 not fertilized with N (Table 14). The result is supported by Singh and Saron (1987) and Shamsuddin *et al.* (1987).

Seed yield

Seed yield was significantly affected by the interaction of variety and nitrogen. Apparently BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} produced the highest seed yield (3.37 t ha^{-1}). The lowest seed yield (0.94 t ha^{-1}) was recorded in BARI Sharisha-13 not fertilized with

N (Table 14). Seed yield showed a positive and linear relationship with harvest index for variety and nitrogen interaction (Fig. 8). Simple linear regression showed that seed yield was highly dependent on harvest index. It can also be concluded that yield of mustard increased with the increases of harvest index. Similar results were observed by Shamsuddin *et al.* (1987); Narang and Singh (1985); Singh and Rathi (1987); Perniola *et al.* (1989); Tarafder and Mondal (1990) and Debowska (1973).

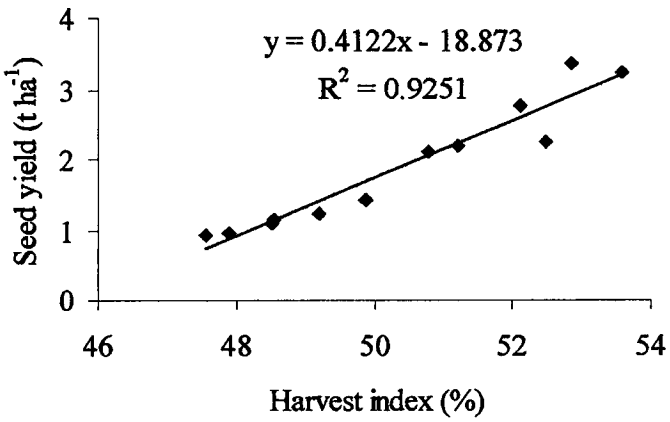

Fig. 8. Functional relationship between harvest index and seed yield of mustard

Stover yield

Stover yield was influenced significantly by interaction between nitrogen and variety. The BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} gave the maximum weight of stover yield (3.00 t ha^{-1}). The lowest weight (1.03) was recorded from the BARI Sharisha-12 and BARI Sharisha-13 fertilized with control (Table 14). The result is supported by Murtaza and Paul (1989).

Table 14. Interaction effect of variety and nitrogen on yield and yield attributes of mustard

Nitrogen x Variety	Siliqua number plant^{-1}			Number of seed per siliqua	Siliqua length (cm)	1000 seed weight (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
	Primary branch	Secondary branch	Total							
$V_1 N_0$	56.23h	61.10h	137.00i	9.00h	2.70j	3.33	1.09h	1.16g	2.25h	48.51fg
$V_1 N_1$	124.93e	85.86f	229.73f	9.80gh	3.10i	3.43	1.43f	1.44e	2.87f	49.87e
$V_1 N_2$	144.56d	126.23d	303.73d	11.00fg	3.86g	3.73	2.78c	2.55c	5.33c	52.13c
$V_1 N_3$	222.26a	242.53a	495.06a	12.56e	4.30f	3.93	3.37a	3.00a	6.37a	52.85b
$V_2 N_0$	50.13i	17.93ij	103.40j	10.06gh	3.16i	2.46	0.95i	1.03h	1.98i	47.89gh
$V_2 N_1$	62.60g	74.30g	166.00h	11.60ef	3.43h	2.56	1.24g	1.28f	2.52g	49.20f
$V_2 N_2$	180.76c	110.70e	329.06c	15.13d	4.53ef	2.86	2.18d	2.08d	4.26de	51.22d
$V_2 N_3$	204.40b	223.33b	449.83b	17.53c	5.03d	3.20	3.24b	2.81b	6.05b	53.57a
$V_3 N_0$	11.28k	15.06j	51.83l	11.93ef	4.60e	3.06	0.94i	1.03h	1.97i	47.56h
$V_3 N_1$	35.53j	20.33i	95.36k	17.00c	5.16c	3.23	1.15h	1.22fg	2.38h	48.54g
$V_3 N_2$	45.33i	85.96f	174.40g	21.16b	6.10b	3.50	2.10e	2.04d	4.14e	50.77d
$V_3 N_3$	72.03f	192.90c	290.73e	24.46a	6.50a	3.86	2.25d	2.04d	4.30d	52.49bc
Level of significance	0.01	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.05
CV (%)	3.05	2.46	1.42	5.58	3.11	1.85	2.20	2.75	2.29	0.77

In a column figures having similar letter (s) do not differ significantly whereas figures having dissimilar letter (s) differ significantly

Note: $N_0 = 0$ kg N ha^{-1}, $N_1 = 46.5$ kg N ha^{-1}, $N_2 = 93$ kg N ha^{-1}, $N_3 = 139.5$ kg N ha^{-1}

V_1 = BARI Sharisha-11, V_2 = BARI Sharisha-12, V_3 = BARI Sharisha-13

NS = Non significant.

Biological yield

The interaction effect of nitrogen and variety on biological yield was also significant which ranged from 1.97 to 6.37 t ha^{-1} (Table 14). BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} produced the highest biological yield (6.37 t ha^{-1}) which differed significantly from other treatments. The lowest (1.97 t ha^{-1}) was found in BARI Sharisha-13 where nitrogen was not applied which was statistically similar to BARI Sharisha-12 fertilized with 0 kg N ha^{-1}. Positive and linear relationships were also obtained when seed yield was plotted against biological yield and at least 99% of the variations in yield could be explained by the variation in biological yield (Fig. 9). The variable biological yield of different mustard varieties were also reported by Ashraf (1997).

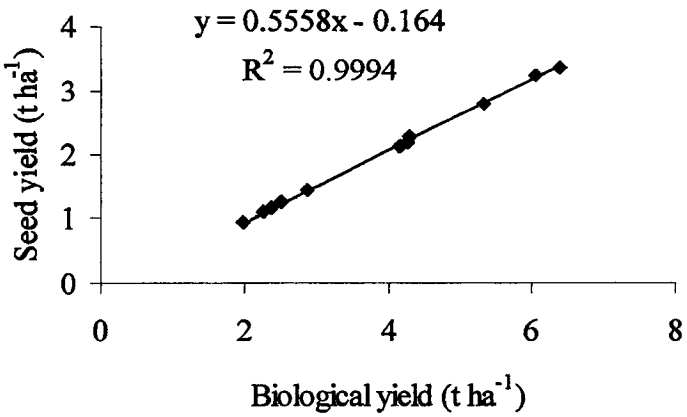

Fig. 9. Functional relationship between biological yield and seed yield of mustard

Harvest index (%)

Interaction effect of nitrogen and variety on harvest index was statistically significant. The highest harvest index (53.56) obtained from variety BARI Sharisha-12 fertilized with 139.5 kg N ha^{-1} (Table 14). The lowest harvest index (47.56) was recorded from variety BARI Sharisha-13 not fertilized with N. Ashraf (1997) and Srivastava *et al.* (1988) found similar results.

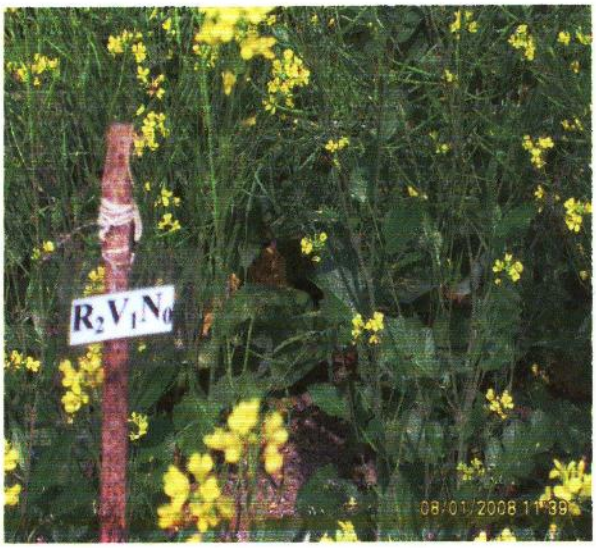

Plate 1. BARI Sharisha-11 with control

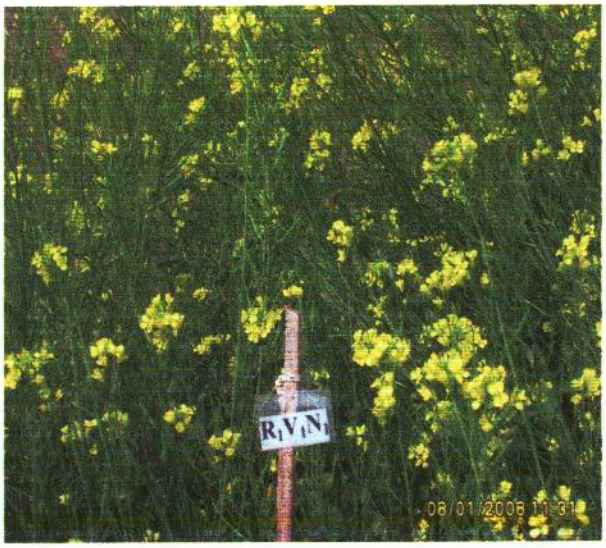

Plate 2. BARI Sharisha-11 with 46.5 kg N ha^{-1}

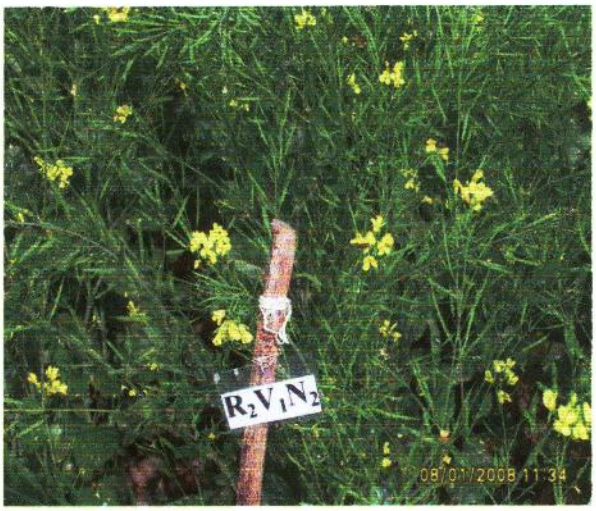

Plate 3. BARI Sharisha-11 with 93 kg N ha^{-1}

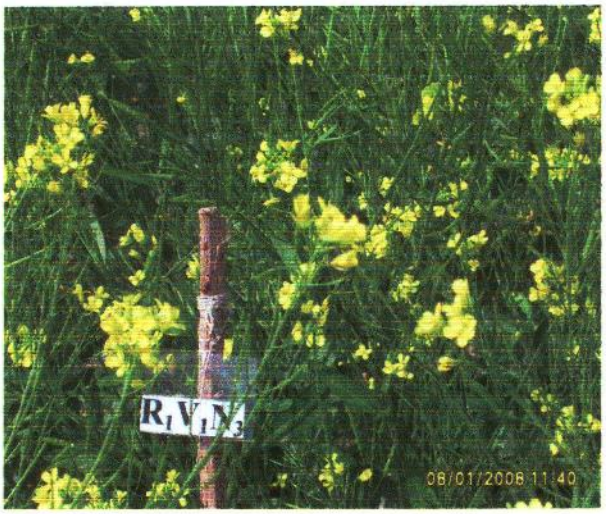

Plate 4. BARI Sharisha-11 with 139.5 kg N ha^{-1}

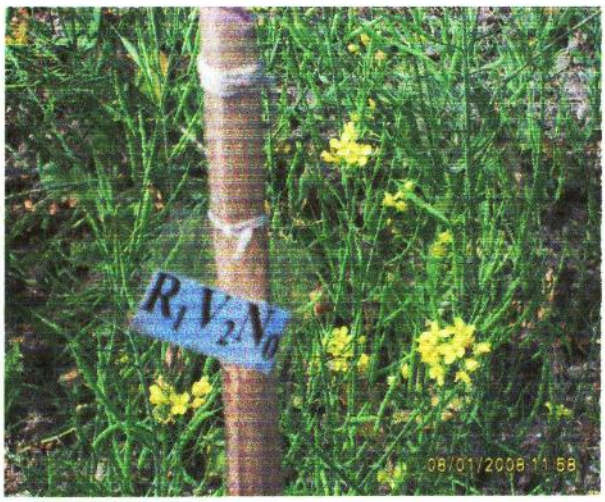

Plate 5. BARI Sharisha-12 with control

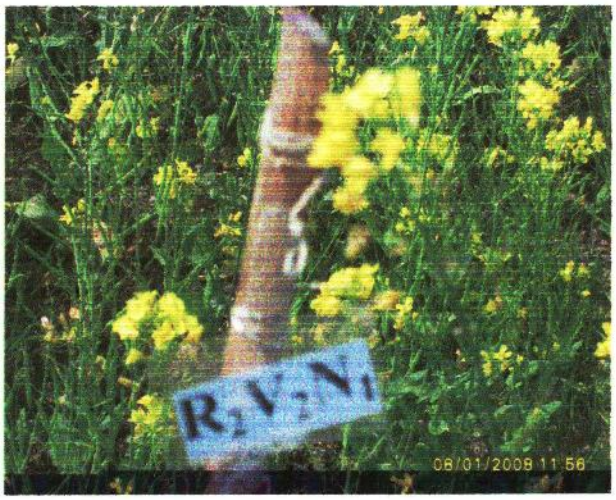

Plate 6. BARI Sharisha-12 with 46.5 kg N ha^{-1}

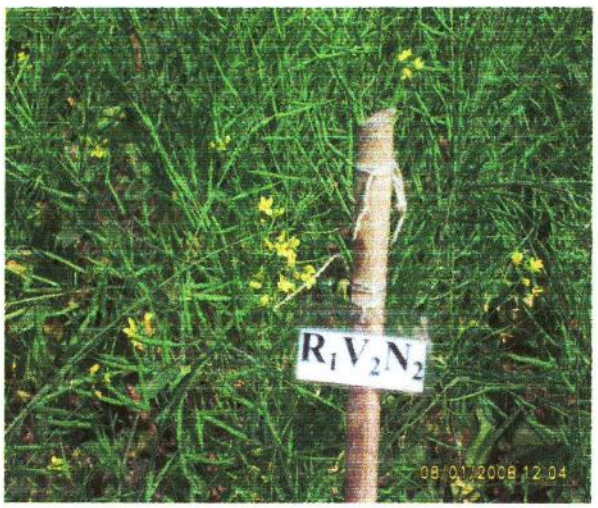

Plate 7. BARI Sharisha-12 with 93 kg N ha^{-1}

Plate 8. BARI Sharisha-12 with 139.5 kg N ha^{-1}

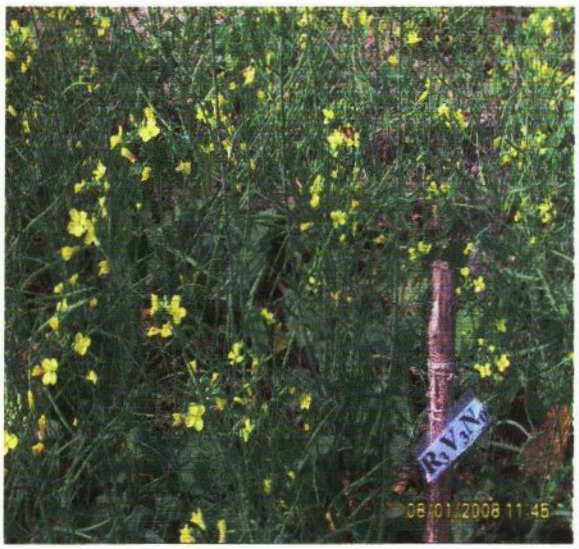

Plate 9. BARI Sharisha-13 with control

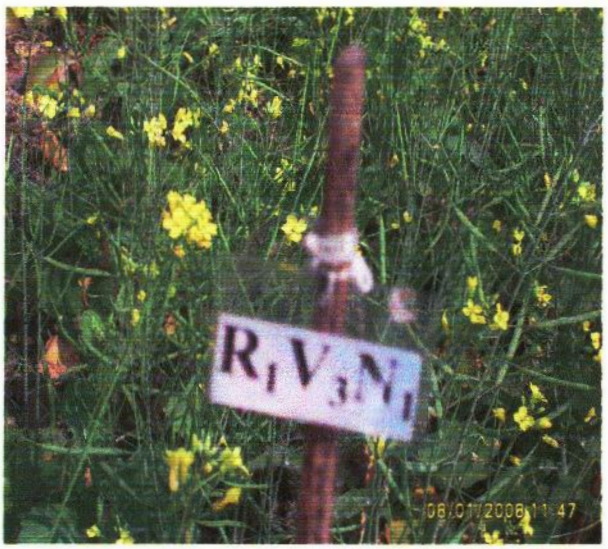

Plate 10. BARI Sharisha-13 with 46.5 kg N ha^{-1}

Plate 11. BARI Sharisha-13 with 93 kg N ha^{-1}

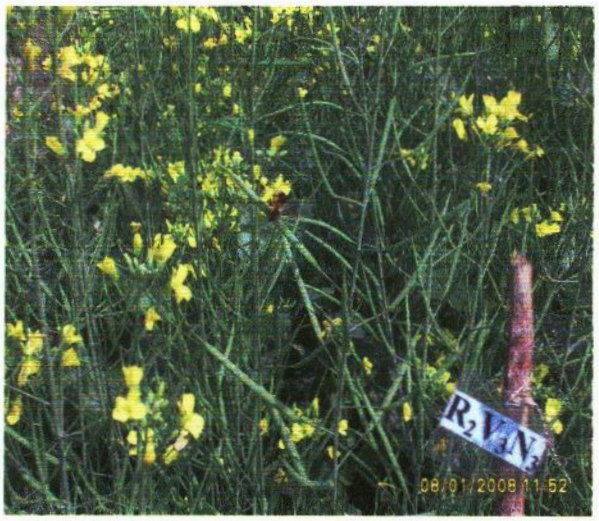

Plate 12. BARI Sharisha-13 with 139.5 kg N ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna from November, 2007 to February, 2008 to study the effect of nitrogen on yield and yield attributes of mustard. The experiment was laid out in Randomized Complete Block Design (RCBD) with two factors. Four levels of nitrogen *viz.* N_0 = 0 kg N ha^{-1}, N_1 = 46.5 kg N ha^{-1}, N_2 = 93 kg N ha^{-1} and N_3 = 139.5 kg N ha^{-1} as well as three varieties of mustard *viz.* V_1= BARI Sharisha-11, V_2 = BARI Sharisha-12 and V_3 = BARI Sharisha-13 were used in this experiment. The experimental land was uniformly fertilized with @ 160, 80, 120, 5 and 12 kg ha^{-1} TSP, MoP, Gypsum, $ZnSO_4$ and H_3BO_4, respectively. Seeds were sown @ 9 kg ha^{-1} on 6th November, 2007 manually in 30 cm apart lines. The seeds were germinated 3 days after sowing (DAS). Flowering commenced at 27, 28 and 30 DAS by BARI Sharisha-12, BARI Sharisha-13 and BARI Sharisha-11, respectively. BARI Sharisha-12 was harvested at 83 DAS and another two varieties were harvested at 92 DAS. After harvesting data were recorded on number of primary branches $plant^{-1}$, secondary branches $plant^{-1}$, total number of branches $plant^{-1}$, number of siliquae per primary branch, number of siliquae per secondary branch, total number of siliqua $plant^{-1}$, number of seeds $siliqua^{-1}$, length of siliqua, 1000-seed weight, seed yield ha^{-1}, stover yield ha^{-1}, biological yield ha^{-1} and harvest index. Plant height and leaf number were counted at ten days intervals regularly after sowing.

The results revealed that varieties differed significantly for all the studied parameters. Among the tested varieties, BARI Sharisha-11 produced the highest plant height (120.09 cm), maximum leaf number (67.35), number of branches $plant^{-1}$ (17.80), number of secondary branches $plant^{-1}$ (12.88), total number of siliqua per plant (291.4), seed yield

(2.16 t ha^{-1}), stover yield (2.04 t ha^{-1}), biological yield (4.20 t ha^{-1}) and harvest index (50.84%) and 1000 seed weight (3.60 g) than other varieties. The highest number of seeds $siliqua^{-1}$ (18.64) and length of siliqua (5.59 cm) were recorded from BARI Sharisha-13 out of three varieties. BARI Sharisha-12 performed well in siliqua number per primary branch (160.30).

Nitrogen fertilization had significant effect on all the studied parameters. Plants receiving the highest dose of N (139.5 kg ha^{-1}) produced the taller plants which were significantly different from plant height obtained in other treatments except at 20 DAS. At 10, 20, 30, 40, 50 and 60 DAS, 139.5 kg N ha^{-1} produced the maximum leaf number of 4.02, 7.63, 11.69, 28.02, 77.09 and 85.16, respectively whereas control treatment produced the minimum leaf number. Highest N dose (139.5 kg ha^{-1}) produced the maximum number of primary branches (6.02), secondary branches (13.2), total branches $plant^{-1}$ (19.22). The maximum number of siliqua per primary branch (166.23), secondary branch (219.58), total siliqua $plant^{-1}$ (411.87), seed number per siliqua (18.18), siliqua length (5.27 cm), 1000- seed weight (3.66 g), seed yield (2.95 t ha^{-1}), stover yield (2.62 t ha^{-1}), biological yield (5.57 t ha^{-1}) and harvest index (52.97 %) were produced @ 139.5 kg N ha^{-1}.

The interaction effect of nitrogen and variety had significant effect on all parameters except plant height and leaf number at 10 DAS, first flowering and 1000 seed weight. The highest plant height (133.80cm), leaf number $plant^{-1}$ (113.40), branch number $plant^{-1}$ (25.53), number of siliquae $plant^{-1}$ (495.06), grain yield (3.37 t ha^{-1}), stover yield (3.00 t ha^{-1}) and biological yield (6.37 t ha^{-1}) observed in BARI Sharisha-11 when nitrogen was applied @ 139.5 kg ha^{-1}. BARI Sharisha -13 gave the highest number of seed $siliqua^{-1}$ (24.46) by the application of nitrogen 139.5 kg ha^{-1}.

It can be concluded from the study, BARI Sharisha-11 performed well than other varieties, nitrogen dose 139.5 kg ha^{-1} was performed best than other doses and BARI Sharisha-11 fertilized with 139.5 kg N ha^{-1} gave the best results in case of most of the parameters.

CHAPTER VI

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