EFFECT OF NITROGEN LEVELS AND ROW SPACING ON GROWTH AND YIELD OF RAPESEED

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CERTIFICATE

This is to certify that the thesis entitled ***" EFFECT OF NITROGEN LEVELS AND ROW SPACING ON GROWTH AND YIELD OF RAPESEED"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfildment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bonafide research work carried out by* ***NUR-E-TANJILA,*** *Registration. No.***09-03330** *under my supervision and guidance. No part of this 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.

Dated:

Dhaka, Bangladesh

(Professor Dr. Md. Shahidul Islam)
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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The Author

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LIST OF ACCRONYMS AND ABBREVIATIONS

Agric. = Agriculture

Agril. = Agricultural

BARI = Bangladesh Agricultural Research Institute

BBS = Bangladesh Bureau of Statistics

BINA = Bangladesh Institute of Nuclear Agriculture

cm = Centimeter

C^0 = Degree Centigrade

DAE = Days after emergence

Dev. = Development

Environ. = Environmental

et al. = and others (at elli)

g = gram (s)

i.e. = idest (L), that is

kg ha^{-1}= Kilogram per hectare

LSD = Least Significant Difference

MoA = Ministry of Agriculture

m = Meter

No. = Number

Sci. = Science

SAU = Sher-e-Bangla Agricultural University

t ha^{-1} = Ton per hectare

Viz. = Namely

Wt. = Weight

% = Percent

EFFECT OF DIFFERENT N LEVELS AND VARIOUS ROW SPACING ON GROWTH AND YIELD OF RAPESEED

ABSTRACT

A field experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to determine the effect of nitrogen levels and row spacing on growth and yield of rapeseed. The experiment consisted of four levels of nitrogen i.e. 69 kg N ha^{-1} (Urea=150 kg ha^{-1})(N_1), 92 kg N ha^{-1} (Urea=200 kg ha^{-1}) (N_2), 115 kg N ha^{-1} (Urea=250 kg ha^{-1}) (N_3) and 138 kg N ha^{-1} (Urea=300 kg ha^{-1}) (N_4); and three row spacing i.e. 20cm (S_1), 30cm (S_2) and 40cm (S_3). The experiment was laid out in a two factors split-plot design with three replications assigning nitrogen levels in the main plot and row spacing in the sub plot. Nitrogen levels, row spacing and their interactions had significant effect on plant height, number of branches plant^{-1}, number of siliquae plant^{-1}, siliqua length, number of seeds siliqua^{-1}, 1000-seed weight, seed yield, stover yield, and harvest index of rapeseed. The application of N @ 115kg ha^{-1} (Urea=250 kg ha^{-1}) (N_3) produced the highest seed yield(1393.3kg ha^{-1})of rapeseed showing the highest value for all the yield parameters except harvest index. The S_2 (30 cm row spacing) treatment produced the highest seed yield (1060.8 kg ha^{-1}) of rapeseed also showing the highest values for the mentioned parameters. Application of N @ 115 kg ha^{-1} with 30 cm row spacing ($N_3 \times S_2$) produced the highest seed yield. The lowest yield was found in N_2 (855.6kg ha^{-1}), S_1 (1140.8kg ha^{-1}) and $N_3 \times S_2$ (1393.3kg ha^{-1}) combination.

CHAPTER I

INTRODUCTION

Rapeseed-mustard (*Brassica* spp.) is an oil seed crop belongs to Cruciferae family and genus *Brassica.* Among the oilseed crops, mustard and rapeseed is in the second position after soybean (FAO, 2014). Total area of mustard and rapeseed in the world is 34.33 million hectares (FAO, 2013). In Bangladesh, *Brassica rapa* L is the main oil yielding species of *Brassica* (FAOSTAT, 2013).

Mustard tops the list among the oilseed crops grown in this country in respect of both production and acreage (BBS, 2011). Mustard seeds contain 40-45% oil and 20-25% protein (Mondal and Wahhab, 2001). Using local ghani average 33% oil may be extracted. Rapeseed-mustard oil is a good source of energy and also it contains fat soluble vitamins; A, D, E and K. The oil cake containing 40% protein is also used as a good source of fertilizer and animal feed and contains applicable quantities of calcium and phosphorus. Dry rapeseed-mustard plants may be used as fuel. It also serves as important source of raw material for industrial use such as in making soaps, paints, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc.

In 2012-2013, the edible oil production from major oilseed crops in the world was 497.9 million tons where rapeseed contributed 64.3 million tons. Total area of mustard and rapeseed in the world is 34.33 million hectares (FAO, 2013).

Rapeseed-mustard is grown more or less all over Bangladesh, but more particularly in the districts of Comilla, Tangail, Jessore, Faridpur, Pabna, Rajshahi, Dinajpur, Kushtia, Kishoregonj, Rangpur, Dhaka (BBS, 2012).

In Bangladesh, rapeseed-mustard is cultivated for different purposes. Mainly it is grown for seedsas an oilseed crop. A substantial area is also used to grow rapeseed-mustard with the aim of using its leaf as green vegetable. It has a remarkable demand for edible oil in Bangladesh. Mustard covers 67% of total oil seed cropped area of Bangladesh and produces about 56% of the total seed requirement (BBS, 2011). It accounts for 59.4% of total oil seed production in the country (AIS, 2010). Bangladesh is running a short of 60-75% of the demand of edible oil (Rahman, 2002).The consumption rate of oil (6 g oil per day per capita) in our country is below the required rate.

In the year 2011-12 it covered 4.83 lakhs ha and the production was 5.25 lakhs Mt and yield was 1.09 lakhs Mt ha^{-1} (AIS, 2013). Our internal production can meet only about 21% of total consumption. The rest 79 % is met by the import (Begum *et al*. 2012). A huge amount of foreign exchanges is required to fulfill the demand of edible oil in Bangladesh by import. It is essential to reduce the import dependence of it to insulate the domestic market from the volatility of the world market (Hossain, 2013). The area and production has been increased in 2013-2014 than 2012-2013. The production was 1.10 ton per hectare in 0.518 million hectare in 2012-2013 and 1.12 ton per hectare in 0.532 million hectare in 2013-2014 due to high yielding varieties of mustard (MOA, 2014).

Rapeseed-mustard is a cold loving crop and grows during Rabi (cold) season (October-February) usually under rainfed and low input condition in this country. Its low yield can be attributed to several factors, the nutritional deficiency, among others is highly important. There is very little scope of expansion for rapeseed-mustard and other oilseed acreage in the country, due to competition from more profitable alternative crops such as boro rice. The area under mustard is declining due to late harvesting of high yielding T.aman rice and increasing boro rice acreage.

Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University(BAU), Bangladesh Institute of Nuclear Agriculture (BINA) and Sher-e-Bangla Agricultural University (SAU) has released a number of new high yielding varieties of rapeseed/mustard for farmer’s cultivation. But the yields in farmer’s fields are still low against to the potentialities.

The cultivation of rapeseed-mustard has to compete with other food grain crops , as a result it has been shifted to marginal lands of poor productivity. With increasing growth rate of population, the demand of edible oil is increasing day by day. It is therefore, highly accepted that the production of edible oil should be increased considerably to fulfil the demand.

The major reasons for poor yield is mainly use of indigenous variety and poor management in using fertilizers as practiced at farmer’s field .The modern variety with mustard growing area need to be expanded by replacing the low yielding local cultivars and the seed yield per unit area is needed to be increased. There is a great scope to improve the yield of rapeseed-mustard per unit area with the use of fertilizers. Nitrogen is considered as one of the important element in order to increase production of quality rapeseed-mustard.

Of all the essential nutrients, nitrogen as an important limiting factor in crop productivity is required by the Mustard in its largest quantity. Plants usually obtain nitrogen by fertilizer application. Nitrogen supports the plant with rapid growth, increasing seed and fruit production and enhancing quality of leaf and oil seed crops. Increased doses of nitrogen increase the vegetative growth and delays maturity of plants.

Majnoun-hosseini *et al*. (2006) and Mobasser *et al*. (2008) suggested that with decrease in planting space and use of nitrogen fertilizer the plant height would be increased. Establishment of optimum plant population by maintaining proper row spacing is one of the important factors to secure a good yield in any crops. In Bangladesh rapeseed-mustard is mostly grown on the residual soil moisture in Rabi (winter) season. Plant density per unit area influences the crop yield considerably. Optimum row spacing ensures proper growth of both aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, land as well as air spaces and water.

In Bangladesh most of the farmers are not aware of using balanced fertilizers. Most of the time they avoid the recommended doses. Many of them apply lower doses or higher doses than the recommended fertilizer doses in rapeseed-mustard. So this hampers the yield and oil content of rapeseed-mustard. But there are not enough research works or information about such imbalanced use of fertilizers by the farmers.

To consider these limitations, a field study using treatments of fertilizer and row spacing was conducted with following objectives-

- To study the growth and yield performance of SAU Sharisha-3 With different N doses
- To evaluate the economic productivity of rapeseed with different row spacing
- To determine the combined effect of row spacing and nitrogen on the yield of rapeseed

CHAPTER II

REVIEW OF LITERATURE

Among the oilseed crops, rapeseed-mustard is one of the common and most important oil crops of Bangladesh and as well as many country of the world. It occupies the topmost position in Bangladesh. The proper fertilizer management essentially accelerates its growth and influences its yield as well as oil content. The work so far done in Bangladesh is not adequate and conclusive. Experimental evidences showed that there is a profound influence of nitrogen and row spacing on this crop. A brief of the relevant works performed in the past are presented in this chapter.

2.1 Effect of nitrogen on mustard

Narits (2010) found that nitrogen fertilization had positive effect on seed yield and seed protein content. On the other hand, nitrogen fertilization, especially in higher rates, had negative effect on oil content.

Mir *et al.* (2010) noted in an experiment that fertilizer dose had significant effect on the yield and yield contributing characters of mustard. The maximum height of plant, number of primary branches, weight of seed 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}.

Chaniyara *et al*. (2002) conducted a experiment in Gujarat at College of Agriculture and emphasized that seed yield was higher at 45 and 15cm inter and intra row spacing respectively. Row spacing of 30 cm produced higher seed yield than 40 and 50 cm spacing (Khan and Tak, 2002).

Seed yield was higher with 30 × 15 cm row spacing as compared to 60 cm row spacing (Shivani *et al*., 2002). In Kanpur, Singh and Prasad (2003) conducted a field experiment at C. S. Azad University of Agriculture and Technology and emphasized that a row spacing of 45 cm resulted in the higher seed yield (2064 kg ha^{-1}). The closer row spacing of 20 cm recorded the lower seed yield of 1343 kg ha^{-1} (Kumar and Singh, 2003).

Venkaraddi (2008) conducted a field experiment at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the response of mustard varieties to date of sowing and row spacing. There were 12 treatment combinations consisting of three varieties (Pusa Agram, Pusa Mahak and EJ-15), two sowing dates (II fortnight of September and I fortnight of October) and two row spacing (30 cm and 45 cm). The mustard variety Pusa Agram recorded significantly higher seed yield (1028 kg ha^{-1}) and oil yield (447.11 kg ha^{-1}). Early sowing during II fortnight of September recorded significantly higher seed yield (888 kg ha^{-1}) and oil yield (387.74 kg ha^{-1}). Row spacing of 30 cm recorded significantly higher seed yield (874 kg ha^{-1}) and oil yield (383.56 kg ha^{-1}).The performance of mustard with respect to growth and yield parameters was significantly superior with variety Pusa Agram, II fortnight of September sowing and 30 cm row spacing. Significantly higher net returns and B: C ratio were recorded with variety Pusa

Agram (16081 Rs. ha^{-1} and 2.14), early sowing during II fortnight of September ((13079 Rs. ha^{-1} and 1.78) and 30 cm row spacing (12600 Rs. ha^{-1} and 1.68). It can be concluded that mustard seed yield (1326 $kgha^{-1}$), oil yield (570.03 kg ha^{-1}), net returns (23107Rs. ha^{-1}) and B: C ratio (3.12) were higher with variety Pusa Agram sown during II fortnight of September at 30cm row spacing.

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30, and 60 kg N ha^{-1} under irrigated or non-irrigated condition in a field experiment. They observed that plant height increased with increasing rate of nitrogen and were higher under irrigated than non-irrigated condition.

Patel *et al.* (2004) during the rabi season of 1999-2000 in Gujarat, India to investigate the effects of irrigation schedule, spacing (30 and 40 cm) and N rates (50, 75 and 100 kg ha^{-1}) on the growth, yield and quality of Indian mustard cv. GM-2. In combination treatments, 3 irrigation + N at 100 kg ha^{-1} + spacing of 45 cm resulted in a significant increase in yield. Growth, yield attributes and seed yield increased with increasing N levels, while oil content decreased with increasing rates. The highest benefit cost ratio was also obtained with N at 100 kg ha^{-1}.Singh *et al.* (2002) also reported that mustard plant height increased significantly with successive increase in nitrogen up to 120 kg ha^{-1}.

Sinsinwar *et al.*(2004) during the 1999/2000 and 2000/01 rabi seasons in Bharatpur, Rajasthan, India, to determine the best cropping sequence and N fertilizer application rate (0, 30, 60 and 90 kg ha^{-1}) of Indian mustard cv. RH-30 under brackish water situation.

The cropping sequences comprised: pearl millet + black gram followed by Indian mustard: pearl millet + pigeon pea followed by Indian mustard; black gram followed by Indian mustard; cluster bean followed by Indian mustard; and fallow followed by Indian mustard. The cropping sequences did not affect the growth, yield and yield components (i.e. plant height, number of primary and secondary branches per plant, number of siliquae per plant), 1000-seed weight and seed yield in both years. The seed yield of Indian mustard significantly increased with each increment of N fertilizer up to 60 kg ha^{-1}, beyond which the increase was marginal. 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^{-1}, respectively. The Indian mustard seed equivalent yield was significantly highest in pearl millet + black gram followed by Indian mustard (3190 kg ha^{-1}) cropping sequence during 1999/2000. In 2000/01, the Indian mustard equivalent yield of pearl millet + black gram followed by Indian mustard was highest (2435 kg ha^{-1}).

Singh *et al*. (2004) reported that nitrogen application did not affect the oil content in mustard but oil yield and chlorophyll content were increased up to 90 kg N/ha over the control. Nitrogen application increased the seed yield of mustard. Nitrogen and sulfur content both in seed and straw and total N and S uptake enhanced due to application of 90 kg N ha^{-1} over its preceding rates. The increased nitrogen and sulfur content enhanced the total uptake of nitrogen and sulfur.

Prasad *et al*. (2003) stated that N at 30 kg ha^{-1} + P at 20 kg ha^{-1} + Zn at 5 kg ha^{-1}, and N at 60 kg ha^{-1} + P at 30 kg ha^{-1} + S at 20 kg ha^{-1} produced the highest growth, yield and productivity, and also good cost: benefit ratio.

Tripathi (2003) in Uttar Pradesh, India in 1994-95 and 1995-96 to investigate the effects of N levels (80, 120, 160 and 200 kg ha^{-1}) on the growth, yield and quality of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and at 60 days after sowing. Results showed that all the yield characters including number of branches increased with increasing N levels up to 160 kg N ha^{-1}, The number of branches per plant increased up to 200 kg N ha^{-1}. Net returns were maximum (Rs. 19 901ha^{-1}) at 160 kg N h^{-1} because seed yield was also maximum at this N rate. The benefit: cost ratio increased up to 160 kg N ha^{-1}, with a maximum of Rs. 209 earned per rupee investment.

Abdin *et al*. (2003) in Rajasthan, Haryana and Uttar Pradesh, India to study the effects of S and N on the yield and quality of Indian mustard cv. Pusa Jai Kisan (V_1) and rape cv. Pusa Gold (V_2). The treatments comprised: T_1 (S0:N50 + 50); T_2 (S40:N50 + 50) for V_1 and (S40:N50 + 25 + 25 for V_2); and T_3(S20 + 20:N50 + 50 for V_1 and S20 + 10 + 10:N50 + 25 + 25 for V_2). Split application of S and N (T_3) resulted in a significant increase in the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t ha^{-1} for V_1 and 3.06 t ha^{-1} for V_2 under T_3. The average oil yield under T_3 was 1.71t ha^{-1} for V_1 and 1.42 t ha^{-1} in V_2. The oil and protein contents in the seeds of V_1 and V_2 also increased with the split application of S and N. It may be concluded from these results that the yield and quality of rapeseed-mustard can be optimized with the split application of 40 kg S ha^{-1} and 100 kg N ha^{-1} during the appropriate phenological stages of crop growth and development.

Khan *et al*. (2003) observed that cycocel at 400 ppm + 60 kg N ha^{-1} and ethrel at 200 ppm + 80 kg N ha^{-1} enhanced leaf photosynthetic rate, water use efficiency, leaf area and leaf dry mass 80 days after sowing. The highest stem, pod and plant dry mass were noted 120 days after sowing. At maturity, pod number and seed yield increased.

Singh and Prasad (2003) stated that among the N rates, 120 kg ha^{-1} gave the highest seed yield (20.24 quintal ha^{-1}), straw yield (12.22 quintal ha^{-1}), stick yield (43.52 quintal ha^{-1}), and net profit (12 975 rupees ha^{-1}). The highest cost benefit ratio (0.85) was obtained with 180 kg N ha^{-1}. [1 quintal=100 kg].

Shingh *et al*. (2003) stated that N at 120 kg ha^{-1} produced 4.51 higher number of branches, 48.03 higher siliqua number, 2.09 g siliqua weight, 2.05 g higher seed weight per plant and 2.55 q ha^{-1} higher seed yield compared to 60 kg N ha^{-1}. The N level higher than 120 kg ha^{-1} did not increase the yield and yield attributes significantly. The basis of N application did not significantly affect the performance of the plants.

Babu and Sarkar (2002) reported that mustard cultivars responded to N application up to 80 kg ha^{-1}. Dry matter yield, N content, N uptake and per cent Ndff by mustard cultivars significantly increased with an increase in the level of fertilizer N. Per cent Ndff significantly increased from 12 at 40 kg N ha^{-1} to 22 at 80 kg N ha^{-1} in mustard seed while in stover the corresponding values ranged from 11 to 20%. Successive levels of N also increased significantly the uptake of soil N by mustard cultivars clearly establishing the ‘priming’ or ‘added nitrogen interaction effect’ of applied nitrogen.

Meena *et al*. (2002) revealed that the application of 60 kg N ha^{-1} registered significantly higher seed and stover yield of mustard over control and 30 kg N ha^{-1} and found statistically at par with 90 kg N ha^{-1}.

Budzynski and Jankowski (2001) stated that the effects of pre-sowing application of NPK (161 kg ha^{-1}) +S (30 kg/ha) or Mg (5 kg ha^{-1}) and top dressing of N (0, 30, 25+5 and 60 kg ha^{-1}) on the yield, yield components and morphological features of white mustard [*Sinapis alba*] and Indian mustard seeds were evaluated in an experiment conducted in Poland. N top dressing (30, 25+5 and 60 kg ha^{-1}) increased the height, diameter of stem base and branching of Indian mustard and white mustard stems. Both crops, however, exhibited lodging. The effects of NPKS and NPKMg on the yield potential of white mustard were not dependent on weather conditions. N applied at 30 kg ha^{-1} at the start of the flowering period gave the best results among the methods of white mustard top dressing. Splitting this rate to 25 kg N ha^{-1} as a solid fertilizer and 5 kg N ha^{-1} in a solution gave results similar to that of the whole rate of 30 kg N ha^{-1} as a solid fertilizer. N at 60 kg ha^{-1} appeared to be less productive. N applied as a solid fertilizer at a rate of up to 60 kg ha^{-1} increased the seed yield. Splitting the N rate to 25 kg ha^{-1} (solid fertilizer) and 4 kg ha^{-1} (solution) gave yield-enhancing effects similar to that of the whole 30 kg N ha^{-1} rate.

Singh (2002) found that application of N and P increased the length of siliqua, number of siliquae per plant, seeds per siliqua, seed yield and 1000-

seed weight of mustard. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N ha^{-1} and 30, 45 and 60 kg P ha^{-1} treatments. The maximum seed yield was recorded from application of 45 kg P ha^{-1} (11.43 and 13.85 q ha^{-1} in 1999 and 2000, respectively) and 120 kg N ha^{-1} (12.98 and 13.83 q ha^{-1} in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was not significant.

Sharawat *et al*. (2002) observed that the yield and oil content generally increased with the increase in N and S rate. N at 120 kg ha^{-1} resulted in the highest number of siliquae per plant (397.25), weight of siliquae per plant (33.32 g), number of seeds per siliqua (14.80), seed yield per plant (368.75 g), 1000-grain weight (17.33 g), seed yield per ha (17.33 quintal) and oil content (38.39%). Saikia *et al*. (2002) stated that dry matter and seed yield affected by different level of N.

Sharma and Jain (2002) reported that the application of 80 kg N/ha resulted in the highest number of branches (24.4) and siliquae (260.9) per plant, number of seeds per siliqua (15.3), 1000-seed weight (5.85 g), and seed yields (1649, 2217, and 1261 kg ha^{-1}).

Patil *et al*. (1997) cultivated B. juncea CV. pusa Bold and B. campestris CV. pusa kalayania under field conditions in New Delhi with 0, 40, 80 and 120 kg N ha^{-1} and observed changes in dry matter accumulation in various plant parts due to the influence of N. The application of N-fertilizer up to 120 kg ha^{-1} had effect on the increasing growth of leaves, stems and pods during the entire period of crop growth.

Tomer *et al*. (1996) reported the highest seed yield of cv. Varuna (2.86 t ha-1) and Pusa (2.72 t ha^{-1}) with the highest dose of N 160 kg ha^{-1} over control. Shahidullah *et al*. (1997) observed in a fertilizer trial with 0, 75, 100 and 150 kg ha^{-1} of N, the seed yield of the B.Juncea CV. Sonali sarisha, Daulat, Tori-5 were increased up to a dose of 100 kg N ha^{-1}. The highest yield was obtained from CV. Sonali sarisha.

Patil *et al*. (1996) reported that the effect on growth, yield components and seed yields of B. juncea that the branching pattern and number of pods produced on different order of branches, in the two species, were favorable modified by the increasing levels of N apply. Primary and secondary branches contributed to the seed yield to an extent of 80% of the total. Yield without any significant effect of N on 1000 seed weight. B. juncea exhibited significantly higher yield than B. campestris. Nitrogen supply up to 120 kg ha^{-1} linearly increased seed yield in both the species.

Kakati and Kalita (1996) found that most of the yield components (branches plant^{-1}, Siliqua plant^{-1}, seed and stover N content) increase with the increasing rate of N-fertilizer, while oil content of seed decreased, 1000 seed weight and number of seeds siliqua^{-1} remained unchanged. The cv. Varuna was found to be highest yielding cultivar.

Dubey and Khan (1991) observed that nitrogen at the rate of 90 kg N ha^{-1} significantly increased seed yield of mustard under irrigated condition. Sharma and Kumar (1990) observed that application of 120 kg N ha^{-1} increased the seed yield of mustard but it is not significantly superior to that of 80 kg N ha^{-1}. With the application of 1 kg N, on and average, produced 11.48 kg seeds against the treatment of 120 kg N ha^{-1}. On the other hand, with the addition of 80 kg N ha-$^{-1}$, 1 kg N produced 10.96 kg seeds.Ali *et al*. (1990) obtained higher seed yield of rapeseed when 90 kg N ha^{-1} was applied under rainfed condition.

Murtaza and Paul (1989) in a pot culture studied three cultivars of rape seed Viz. Pola, Tori-7 and Sampad grown with four levels of N-Fertilizer (0, 5, 10, 20 g of urea) observed significant effect of nitrogen on the number of primary branches plant^{-1}, siliqua plant^{-1} seed siliqua^{-1} and weight and seed yield plant^{-1}. The cultivars showed significant differences in all the characters except the number of primary branches and siliqua plant^{-1}.

Patel *et al*. (1980) performed a field experiment with four levels of nitrogen (viz. 0, 25, 50 and 75 kg ha^{-1}). They reported that different levels of nitrogen gave different seed yields of mustard significantly. The highest seed yield was 0.73 t ha^{-1} achieved at the rate of 50 kg N ha^{-1} due to the formation of higher no. of secondary branches plant^{-1}, higher no. of siliquae plant^{-1} and higher harvest index.

2.2 Effect of row spacing

2.2.1 Plant height

Chauhan *et al*. (1993) reported no significant effect of row spacing on the plant height of toria. They evaluated three row spacing viz 20, 30, and 40 cm. The maximum plant height was found at 20 cm row spacing which was similar to the plant height found at 30 cm row spacing and lowest at 40 cm row spacing. It showed that plant height decreased with the increase of row spacing.

Sharma and Thakur (1993) reported positive relationship between plant height and increasing row spacing of rapeseed. During 1988 -1989 among three row spacing of 30, 37.5 and 45 cm for the sowing of rapeseed, they found the tallest plant with 45 cm row spacing which was higher than 37.5 cm and 30 cm row spacing. But the effect was not statistically influenced.

2.2.2 Number of branches plant^{-1}

Thakur (1999) conducted a field experiment at Himachal Pradesh Krishi Vishwavidyalaya, Kangra and observed that number of primary and secondary branches plant $^{-1}$ was higher in 30 cm row spacing as compared to 20 cm row spacing.

Gurjar and Chauhan (1997) conducted a field experiment in Gwalior and reported that primary and secondary branches plant $^{-1}$ recorded significantly higher with 30× 15 cm row spacing (6.72 and 21.57 branches plant^{-1}) as compared to 45 × 15cm (5.80 and 16.76 branches plant^{-1}) .

Shrief *et al*. (1990) maintained population density of 30, 60 and 90 plants m-2 for raising rapeseed and claimed positive response of all yield contributing characters. They found that number of branches plant^{-1} was significantly superior in the plant density of 30 plants m^{-2} compared to those from 60 and 90 plants m^{-2}.

2.2.3 Siliquae plant^{-1}

Hasanuzzaman (2008) carried out an experiment at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka-1207, Bangladesh. Accumulation of dry matter in siliqua, number of siliquae plant^{-1} , length of siliqua and seeds per siliqua of rapeseed (*Brassica campestris* L.) plants were studied under three irrigation levels (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS) and three row spacing (20 cm, 30 cm and 40 cm). Number of siliquae plant^{-1}was affected by different irrigation levels and row spacing and the highest number of silique was produced by two irrigations (at 30 DAS and 60 DAS) with 40 cm row spacing.

Butter and Aulakh (1999) conducted a study on Indian mustard cv. RLM 619 and maintained 3 rows spacing (15, 22.5 and 30 cm). They observed that row spacing had significant effect on number of siliquae plant^{-1} and found increased number of siliquae plant^{-1} with wider row spacing (40 cm).

Thakur (1999) conducted a field experiment at Himachal Pradesh Krishi Vishwavidyalaya, Kangra and observed that number of siliquae plant^{-1} were higher in 30 cm row spacing. Row spacing had remarkable effect in producing more number of fertile siliquae plant^{-1}. Wider spacing facilitated favorable environment for producing more siliquae than closer spacing (Siddiqui, 1999).

Gurjar and Chauhan (1997) conducted a field experiment in Gwalior and observed that number of siliquae plant-1 recorded higher with 30 cm × 15 cm row spacing (444) as compared to 45 cm × 15 cm row spacing (356).

Thakuria and Gogoi (1996) conducted a field experiment to evaluate *Brassica juncea* cv. TM 2, TM 4 and Varuna at 2 row spacing (30 and 45 cm). The effect of cultivars and row spacing on seed yield and yield attributes was significant except siliquae plant^{-1} which increased at 45 cm row spacing.

Sharma (1992) conducted a field experiment at College of Agriculture, Gwalior (Madhya Pradesh) and concluded that a row spacing of 30 cm recorded higher number of siliquae plant^{-1} (233.4) as compared to 45 cm row spacing (228.4).

2.2.4 Length of siliqua

Hasanuzzaman (2008) carried out an experiment at Sher-e-Bangla Agricultural University (SAU) Farm where plants were studied under three irrigation levels (no irrigation, one irrigation at 30 DAS and two irrigations at 30 and 60 DAS) and three row spacing (20 cm, 30 cm and 40 cm). Length of siliquae as well as number of seeds per siliqua was significantly affected by the combination of irrigation levels and row spacing.

Singh and Verma (1993) quoted that higher length of siliqua with 60 cm row spacing (4.26 cm) was observed as compared to 30 cm row spacing (4.14 cm).

2.2.5 Number of seeds siliqua^{-1}

The number of seeds siliqua^{-1} contributes materially towards the final grain yield in rapeseed. So, the number of seeds siliqua^{-1} is an important yield attributes of rapeseed and mustard and population density is a vital factor in producing optimum number of seeds siliqua^{-1}.

Hasanuzzaman (2008) carried out an experiment at Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka-1207, Bangladesh and stated that number of seeds siliqua^{-1} were significantly affected by the combination of irrigation levels and row spacing.

In Kanpur, Yadav *et al*. (1994) revealed that a row spacing of 45 cm × 20 cm recorded significantly higher number of seeds siliqua^{-1} (15) as compared to 45 cm× 10 cm (13.0).

Singh and Verma (1993) quoted that a row spacing of 60 cm recorded greater number of seeds siliqua^{-1} (11.55) compared to 30 cm row spacing (10.80). Sharma (1992) conducted a field experiment at College of Agriculture, Gwalior (Madhya Pradesh) and concluded that row spacing of 45 cm recorded more number of seeds siliqua^{-1} (14.18) as compared to 30 cm row spacing (13.10).

Mishra and Rana (1992) also reported that a row spacing of 60 cm recorded higher number of seeds siliqua^{-1} (13.2) as compared to 30 cm or 45 cm row spacing (13.1).

2.2.6 1000-seed weight

It is also an important character which reflects the seed size. It varies from genotype to genotype and is influenced by some production factors. A good number research works have been conducted on this character.

Chauhan *et al*. (1993) reported a positive relation between row spacing and 1000-seed weight. They found a significant effect of row spacing (20, 30 and 40 cm) on 1000-seed weight of Toria. Among the row spacing 40 cm row spacing gave highest weight of 1000-seeds while 20 cm row spacing gave lowest weight.

Sharma (1992) found a significant increasing rate of 1000-seed weight with the increase of row spacing in different mustard varieties. He conducted an experiment with four row spacing viz. 30.0, 33.5, 37.5 and 45.0 cm. Among all row spacing maximum seed weight was found from 45 cm row spacing which was significantly higher from others. Lowest seed weight was found from 33.5 cm row spacing.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the research field of Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2015 to February 2016. The materials and methods of this experiment are presented in this chapter under the following headings-

3.1 Experimental site

The present piece of research work was conducted in the field of Agronomy Department, Sher-e-Bangle Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the site was 23°74'N latitude and 90°35' E longitude at an altitude of 8.6 meter.

3.2 Characteristics of soil

The soil of the experimental site belongs to the agro-ecological region of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. Land was medium high with medium fertility level. The soil physical and chemical properties have been shown in Appendix- II and III respectively.

3.3 Weather condition of the experimental site

The geographical situation of the experimental site was under the subtropical climate, characterized by three distinct seasons, the monsoon of rainy season from November to February, and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*. 1979). During the rabi season the rainfall generally is scant and temperature moderate with short day length. Meteorological data on rainfall, temperature, relative humidity from November 2015 to February 2016 were obtained from the Department of Meteorological centre, Dhaka-1207, Bangladesh (Appendix I).

3.4 Materials of the experiment

3.4.1 Collection of plant materials

The experiment was done with a new variety of rapeseed named SAU Sarisha-3. The seeds of this variety were collected from Sher-e-Bangla Agriculture University Farm. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.4.2 Experimental treatments

There were two treatment factors in this experiment, viz., N levels and row spacing comprised of four doses of nitrogen and three row spacing. The experiment was designed with two factors:

Factor A: Nitrogen levels (4 levels)

N_1=69 kg ha^{-1} (Urea=150 kg ha^{-1})

N_2=92 kg ha^{-1} (Urea=200 kg ha^{-1})

N_3=115 kg ha^{-1} (Urea=250 kg ha^{-1})

N_4=138 kg ha^{-1} (Urea=300 kg ha^{-1})

Factor B: Row spacing (3 levels)

S_1=20cm × 5cm

S_2= 30cm × 5cm

S_3= 40cm × 5cm

3.5 Experimental design and layout

The experiment was laid out in split plot design with three replications. Nitrogen was assigned in main plot and row spacing in the sub-plot. There were a total of 36 unit plots. The size of each plot was 3m×2m. Distances between replication to replication and plant to plant were 0.5m and 5cm, respectively (Appendix II).

3.6 Land preparation

The land was ploughed and cross-ploughed three times followed by laddering to obtain the desired tilth and larger clods were broken into smaller pieces after ploughing and laddering all the stubbles and uprooted weeds were removed and the land was made ready. Seeds were sown on 7 November, 2015.

Light irrigation was given along the rows immediate after sowing to ensure maximum germination. Other appropriate cultural management practices were done properly to ensure a good stand of the crop.

3.7 Fertilizer application

The experimental land was fertilized with TSP, MoP, Gypsum, Zinc sulphate and Borax fertilizers @ 81, 51, 27, 3.9, and 1 kg ha^{-1} respectively. The whole amount of TSP, MoP, Gypsum, Zinc sulphate and Borax were applied as basal dose at final land preparation. N was applied in the form of urea as per treatment. Half of urea was applied during final land preparation and rest half was applied before flowering.

3.8 Weeding and thinning

Two weeding and thinning were done respectively at 15 days after emergence and 30 days after emergence (DAE).

3.9 Crop sampling and data collection

To study growth characteristics, three plants were randomly selected and uprooted from each plot at each sampling to collect data on some morphological, yield and yield attributes. The first sampling was done at 15 days after emergence (DAE) and continued at an interval of 15 days up to 75 DAE and finally at maturity (80 DAE).

3.10 Harvesting and processing

The crop was harvested at the 90% of the siliquae maturity on 31 January 2016 at 80 days after emergence (DAE). Before harvesting the whole plot, 3 plants were randomly selected from each plot for collecting data on yield attributes. The sample plants were uprooted prior to harvest and dried properly under the sun and collected data from these plants. The seed and stover yields were measured from the plot after harvesting, cleaning and drying the plants from central 1.0 m^2 area in each plot.

3.11 Recording of data

3.11.1 Growth parameters

i. Plant height

ii. Number of branches $plant^{-1}$

iii. Total dry matter

3.11.2 Yield parameters and yield

i. Number of siliquae $plant^{-1}$

ii. Number of seeds $siliqua^{-1}$

iii. Length of siliqua

iv. 1000-seed weight

v. Seed yield

vi. Stover yield

3.12 Procedures of data collection

3.12.1 Plant height

The height of the plants at 15, 30, 45, 60, 75 days after emergence and at maturity were measured from the base of the plant to the tip of the main stem and mean value of the plant heights were finally recorded.

3.12.2 Number of branches plant^{-1}

The number of primary and secondary branches was counted plant-^{1}and mean values were taken.

3.12.3 Dry matter weight plant^{-1}

For dry matter estimation the sampled plants were separated into their components viz. stem, leaves, root and reproductive parts; then dried for 72 hours and weighed.

3.13 Yield parameters and yield

3.13.1 Number of siliquae plant^{-1}

Siliquae of three randomly selected plants of each plot were counted and then the average number of siliquae plant^{-1} was determined.

3.13.2 Number of seeds siliqua^{-1}

After shedding of the siliqua seed numbers was recorded from randomly selected 10 siliquae and finally mean value was calculated.

3.13.3 Length of siliqua

Siliqua length was recorded from the base to the apex of each siliqua of 10 randomly selected siliqua. Then mean value was calculated.

3.13.4 1000-seed weight

One thousand clean sun dried seeds were counted from the seed stock collected from the sample plants and weighed by electronic balance expressing in gram.

3.13.5 Seed yield

Total mustard plants were collected from pre selected area (1.0 m^2) of the middle of each plot. The plants were cut, threshed and dried. The dried seeds were weighed. Then the weighed seed yield was converted to t ha^{-1}.

3.13.6 Stover yield

Straw yield was determined from the central $1m^2$ of each plot. After threshing, the samples were oven dried to a constant weight.

3.14 Statistical analysis

Data recorded were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done with the help of computer package MSTAT-C by LSD at 5% level of significance.

CHAPTER IV

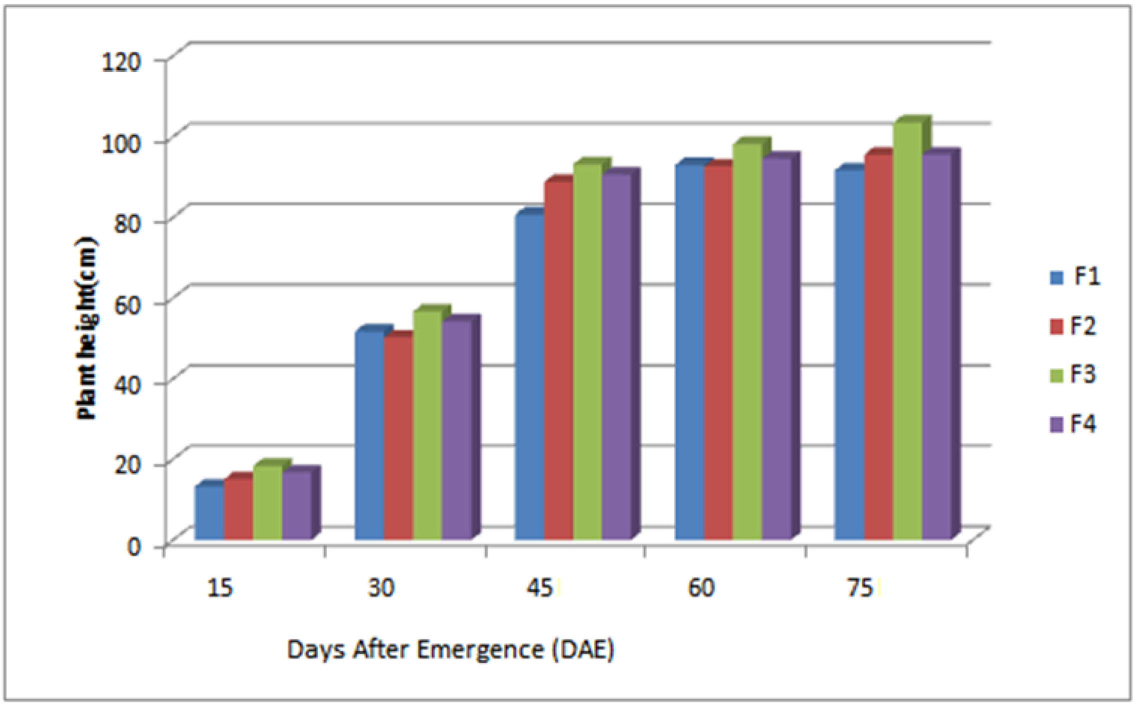
RESULT AND DISCUSSION

A field experiment was conducted to determine the effect of nitrogen levels and various row spacing on growth and yield of rapeseed.The results have been presented and discussed for the convenience of easy understanding under the following headings:

4.1 Effect on growth parameters

4.1.1 Plant height

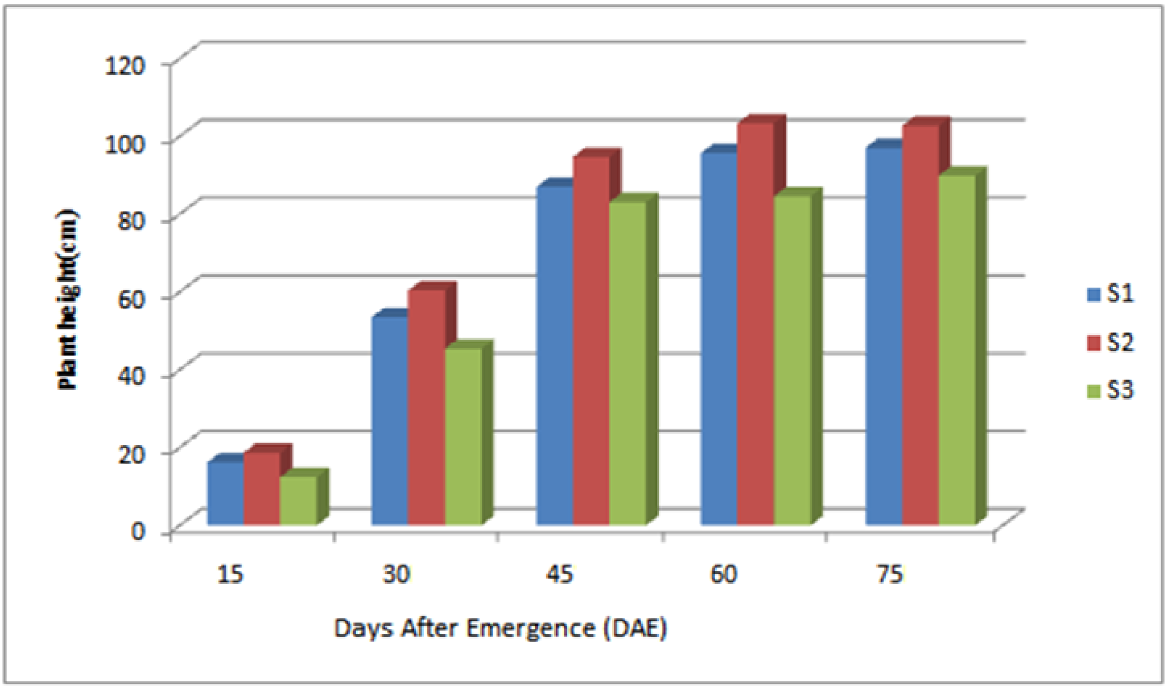
Nitrogen levels significantly influenced the plant height of rapeseed (cv. SAU Sharisha-3) at different days after emergence (DAE) (Figure 1). At all the growth stages studied, plant height increased with the increasing rate of nitrogen up to 115 kg ha^{-1}, thereafter it declined. The highest plant height were found 18.28 cm at 15DAE, 56.61 cm at 30DAE, 93.12 cm at 45DAE and 98.22 cm at 60DAE with N_3 (115 kg ha^{-1}). The lowest plant height were 13.18 cm at 15DAE, 80.66 cm at 45DAE with N_1 (69 kg ha^{-1}).At 30DAE N_2 (92 kg ha^{-1}) had the lowest plant height (50.16 cm). At maturity the highest plant height (103.52 cm) of mustard was found with 115 kg ha^{-1} of N which was followed by 138 kg ha^{-1}(95.59 cm), 92 kg ha^{-1} (95.54cm) and 69 kg ha^{-1} (91.61cm). The lowest plant height at maturity was found with N_1 (69 kg ha^{-1}) which was 91.61 cm. These findings corroborated with the results reported by Rahman (2003), Hasan and Rahman (1989), Shamsuddin *et al*. (1987) and Mondal and Gaffer (1983). They found that the application of N increased the plant height significantly.



Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

Figure 1. Effect of nitrogen levels on plant height of rapeseed at different days after emergence ($LSD_{0.05}$=1.81, 5.71, 6.19, 8.62, and 8.19 at 15, 30, 45, 60 and 75DAE, respectively)

The significant effect of row spacing was found on plant height (Figure 2). The maximum plant height (102.73 cm) was observed at 30 cm row spacing (S_2) which was followed by 20 cm (97.07cm) and 40 cm row spacing(89.90cm) (S_1 and S_3 respectively). The widest row spacing of 40 cm (S_2) gave the lowest plant height (89.90 cm) at all growth stages. 30 cm row spacing provided highest plant height at 15DAE (18.73 cm), 30DAE (60.43 cm), 45DAE (94.73 cm), and 60DAE (103.42 cm). Spacing determines the microclimate in the crop field. The results obtained in this experiment might be due to the optimum microclimate provided by 40 cm row spacing.



Here, S_1=20 cm×5 cm S_2=30cm×5cm S_3=40cm×5cm

Figure 2. Effect of row spacing on plant height of rapeseed at different days after emergence ($LSD_{0.05}$=1.04, 3.29, 4.76, 3.89 and 3.99 at 15,30, 45, 60 and 75DAE , respectively)

The interaction between effect of nitrogen levels and row spacing on plant height was significant (Table 1). N_3×S_2 combination had highest plant height at all growth stages. At 15DAE N_1×S_3 (10.94cm) and N_2×S_3 (10.79cm)combination had lowest results. N_2×S_3 combination had lowest result at 30DAE (42.7cm) and N_1×S_3 had lowest results at 45(72.52cm) and 60DAE(81.83cm). At 75DAE the highest plant height was recorded 113.07 cm when 115 kg ha^{-1} N (N_3) was applied with 30 cm row spacing(S_2). The lowest plant height was 83.33 cm with the application of 69 kg ha^{-1} N (N_1) fertilizer with 40 cm row spacing (S_3), which was statistically similar to N_1×S_1, N_2×S_1, N_3×S_3 and N_4× S_3.

Table 1: Interaction effect of nitrogen levels and row spacing on plant height of mustard at different days after emergence (DAE)

Treatment	Plant height (cm) at				
	15 DAE	30 DAE	45 DAE	60 DAE	75 DAE
$F_1 \times S_1$	13.8 de	48.5 cde	80.17 cd	95.39 bc	89.43 de
$F_1 \times S_2$	14.8 de	60.87 ab	89.3 abc	101.67 ab	102.07 bc
$F_1 \times S_3$	10.94 f	45.61de	72.52 d	81.83 d	83.33 e
$F_2 \times S_1$	14.83 cde	50.5 cd	86.4 bc	91.67 bcd	92.81 cde
$F_2 \times S_2$	19.33 ab	57.27 ab	93.64 ab	101.07 ab	99.7 bcd
$F_2 \times S_3$	10.79 f	42.7 e	86.02 bc	85.04 cd	94.11cd
$F_3 \times S_1$	18.8 ab	59.69 ab	90.48 ab	99.24 b	104.86b
$F_3 \times S_2$	20.43 a	63.6 a	99.13 a	110.3 a	113.07 a
$F_3 \times S_3$	15.6 cd	46.53 de	89.76 abc	85.13 cd	92.63cde
$F_4 \times S_1$	17.3 bc	55.41 bc	90.94 ab	96.61b	101.17 bc
$F_4 \times S_2$	20.37 a	60.0 ab	96.83 a	101.67 ab	96.07 bcd
$F_4 \times S_3$	12.37ef	46.97de	84.06 bc	86.4cd	89.53 de
$LSD_{(0.05)}$	2.47	7.81	9.92	10.69	10.44
CV (%)	7.58	7.14	6.23	4.48	4.77

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

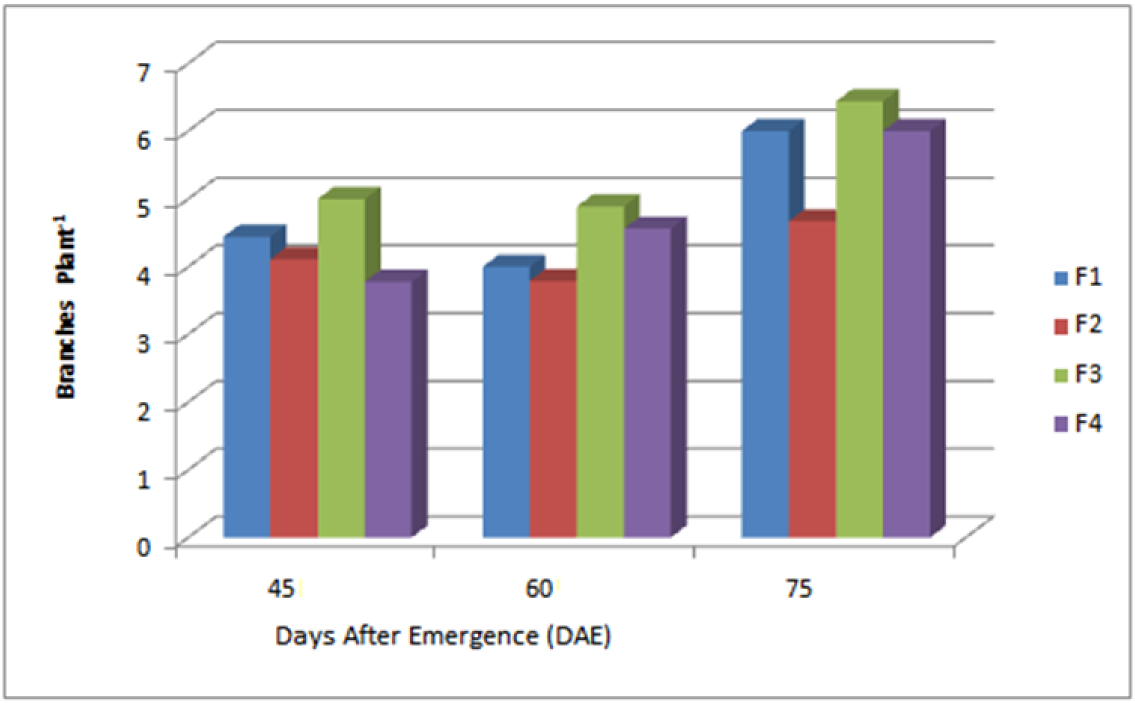
Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

S_1=20 cm×5 cm S_2=30cm×5cm S_3=40cm×5cm

4.1.2 Number of branches plant^{-1}

The significant variations in number of branches plant^{-1} were observed for different nitrogen levels (Figure 3). The result showed that the highest number of branches plant^{-1} (5.00) was found from 115 kg ha^{-1} N application and the lowest (3.78) was recorded with 138 kg ha^{-1} N application at 75DAE. The application of N @ 69 kg ha^{-1} and 92 kg ha^{-1} produced 4.44 and 4.11 branches plant^{-1}respectively. At 45 and 60DAE N_3 had highest number of branches plant^{-1} and others were statistically similar. AT 75DAE N_2 had lowest result(4.67). Probably 115 kg N ha^{-1} ensured the favorable condition for growth of mustard and the ultimate results is the maximum number of branches. Mondal and Gaffer (1983), Gaffer and Razzaque (1983) also reported the similar results from their experiments. They reported that increasing levels of nitrogen significantly increased branches plant^{-1} of mustard.

Significant variations were found in number of branches plant^{-1} due to spacing (Figure 4).The highest number of branches plant^{-1} (7.5) was found in S_2 (30 cm row spacing) treatment and the lowest value was 4.5 with S_3 (40 cm row spacing) treatment at all the stages except 45 DAE. At 45 DAE, the lowest value was found in S_1 treatment (20 cm row spacing) (3.83).

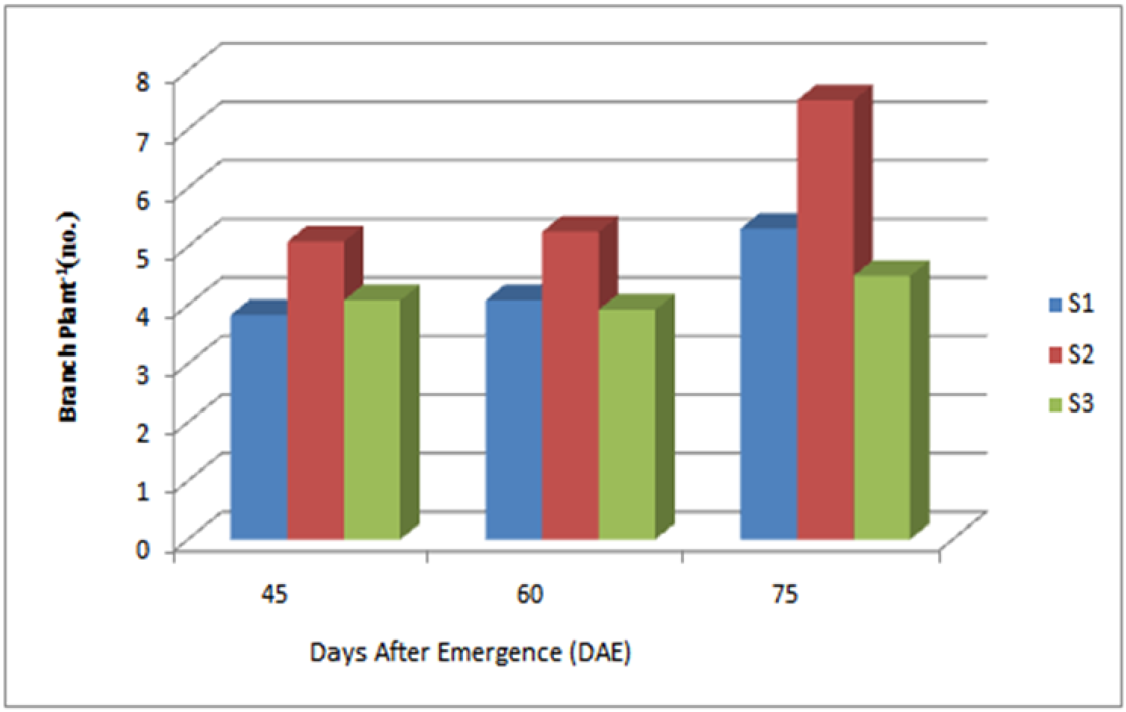


Here, N_1=69 kg ha^{-1} N_2=92kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

Figure 3. Effect of nitrogen levels on number of branches plant^{-1} of rapeseedat different days after emergence ($LSD_{0.05}$=0.67, 1.09, 1.29 at 45, 60 and 75 DAE, respectively)

The interaction effect on number of branches plant^{-1} was recorded highest with $N_2 \times S_2$ (5.67) and $N_3 \times S_2$ (5.33) treatment which were statistically similar to the combinations $N_1 \times S_1$, $N_1 \times S_2$, $N_1 \times S_3$,$N_3 \times S_1$,$N_3 \times S_3$ and $N_4 \times S_2$. $N_4 \times S_1$ (3.0) treatment had the lowest value at 45 DAE (Table 2). At maturity 115 kg ha^{-1} N and 30 cm spacing had the highest value (8.0) in case of number of branch plant^{-1} (Table 2) which was statistically similar to $N_1 \times S_2$, $N_2 \times S_2$ and $N_4 \times S_1$.

In rapeseed reduced number of branches plant^{-1} due to increasing population density has been reported by Singh and Dhillon (1991) and Singh and Verma (1993).



Here, S_1=20 cm×5cm S_2=30 cm×5cm S_3=40 cm×5cm

Figure 4. Effect of row spacing on the number of branches plant^{-1} of mustard at different days after emergence ($LSD_{0.05}$=0.75, 0.74 and 0.69 at 45, 60 and 75 DAE, respectively)

Table 2. Interaction effect of nitrogen levels and row spacing on the number of branches plant^{-1} of mustard at different days after emergence (DAE)

Treatment	Number of branches plant^{-1}		
	45 DAE	**60 DAE**	**75 DAE**
$N_1 \times S_1$	4.33abcd	3.67 bcd	5.33cdef
$N_1 \times S_2$	4.67abc	5.33a	7.67ab
$N_1 \times S_3$	4.33abcd	4.33abcd	5.0def
$N_2 \times S_1$	3.33cd	5.0ab	3.67fg
$N_2 \times S_2$	5.67a	5.0ab	7.33ab
$N_2 \times S_3$	3.33cd	3.67bcd	3.0g
$N_3 \times S_1$	4.67abc	4.67abc	6.0bcde
$N_3 \times S_2$	5.33a	5.67a	8.0a
$N_3 \times S_3$	5.0ab	4.33abcd	5.33cdef
$N_4 \times S_1$	3.00d	5.0ab	6.33abcd
$N_4 \times S_2$	4.67abc	5.0ab	7.0abc
$N_4 \times S_3$	3.67bcd	3.67bcd	4.67efg
$LSD_{(0.05)}$	1.39	1.63	1.72
CV (%)	19.99	19.43	13.98

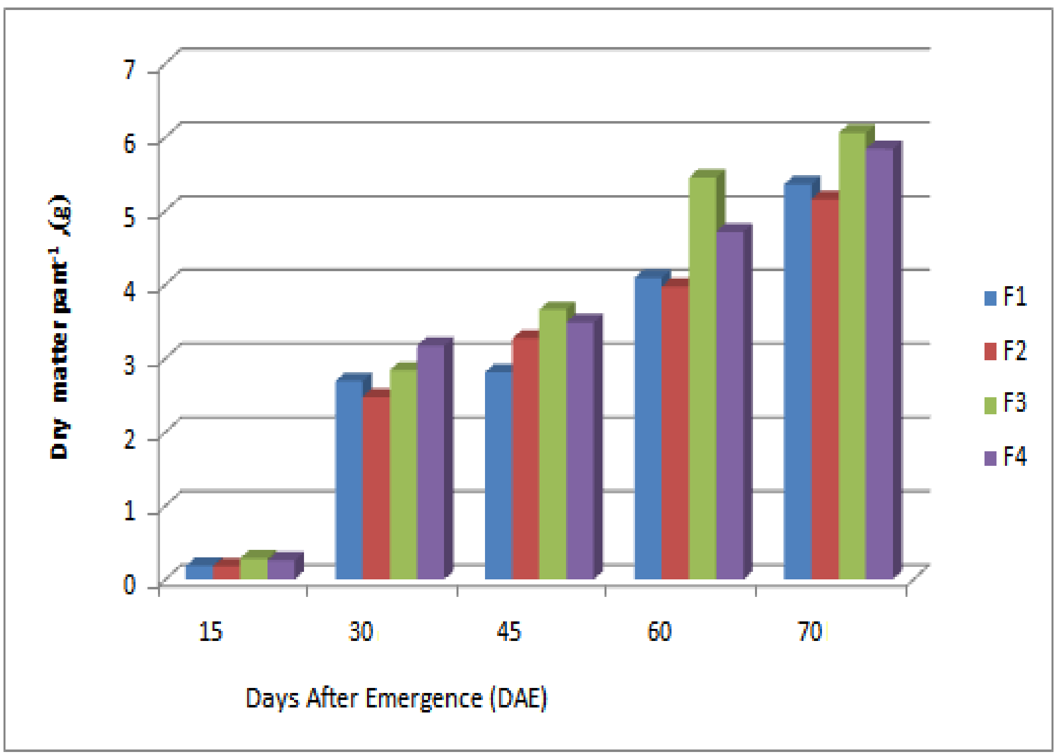
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

S_1=20 cm×5 cm S_2=30cm×5cm S_3=40cm×5cm

4.1.3 Dry matter weight plant^{-1}

Different nitrogen levels showed significantly different dry matter weight plant^{-1} at different days after emergence (DAE) (Figure 5). At all the growth stages the dry matter plant^{-1} was highest in N_3 (115 kg ha^{-1}) treatment like 0.29g at 15DAE, 3.67g at 45DAE, 5.45g at 60DAE and 6.06g at 75DAE except 30DAE where N_4 (138kg ha^{-1}) had highest result (3.17g). The lowest value were found in N_2 (92 kg ha^{-1}) treatment at 30, 60 and 75 DAE, where-as in N_1 (69 kg ha^{-1}) at 15 and 45 DAE.



Here, N_1=69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

Figure 5. Effect of nitrogen levels on dry matter plant^{-1} of mustard at different days after emergence ($LSD_{0.05}$=0.05, 0.49, 0.61,0.97 and 0.78 at 15, 30, 45, 60 and 75 DAE, respectively)

The effect of row spacing on dry matter plant^{-1} was found significant at different days after emergence except 15 and 60 DAE (Figure 6). The effect of row spacing on dry matter plant^{-1} was recorded the highest (6.29 g) at 30 cm row spacing (S_2) and lowest (4.89 g) at 40cm row spacing (S_3) at maturity stage. At 15, 30, 45 DAE the highest results were 0.28, 3.11, 3.98 with 30 cm row spacing (S_2) and lowest values were 0.19, 2.62, 2.61.

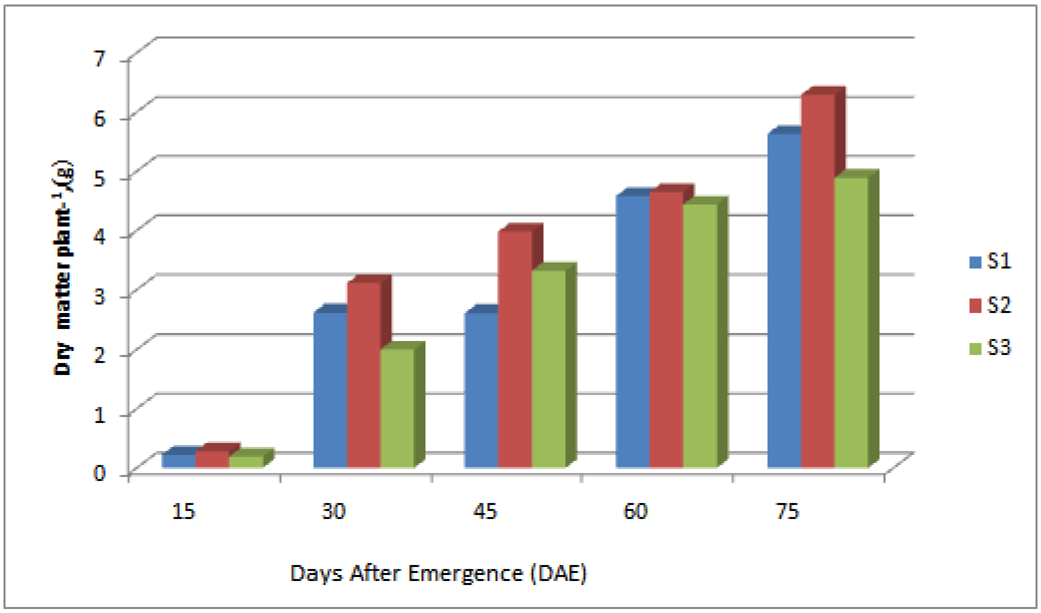


Figure 6.Effect of row spacing on dry matter plant^{-1} of mustard at different days after emergence ($LSD_{0.05}$=0.03, 0.33 , 0.28,1.02 and 0.48 at 15, 30, 45, 60 and 75 DAE, respectively)

Here, S_1=20 cm×5cm S_2=30 cm ×5cm S_3=40 cm×5cm

Dry matter plant^{-1} was significantly influenced by the interaction of N levels and row spacing (Table 3). The highest dry matter plant^{-1} was obtained from $N_4 \times S_2$ (6.61 g) which was statistically similar to $N_3 \times S_1$ (6.59 g), $N_3 \times S_2$ (6.50g) and $N_4 \times S_1$ (6.19 g) treatment combinations at 75DAE. The lowest total dry matter plant^{-1} was obtained from treatment combination $N_2 \times S_3$ (4.71 g) which was statistically similar to that of $N_4 \times S_3$ (4.73 g) and $N_2 \times S_1$

(4.74 g). These results were supported by Saikia *et al.* (2002) and Patil *et al.* (1997). They found that application of N increased the total dry matter plant^{-1} of mustard. At 15DAE $N_3 \times S_2$ (0.32g) and $N_4 \times S_1$ (0.31g) were found highest and $N_1 \times S_1$ (0.13g) was the lowest. $N_4 \times S_2$ (3.39g) , $N_3 \times S_2$ (4.26) and $N_3 \times S_3$ (6.05g) were highest at 30, 45 and 60DAE.

Table 3: Interaction effect of nitrogen levels and row spacing on dry weight plant^{-1} of mustard at different days after emergence (DAE)

Treatment	Plant height (cm) at				
	15 DAE	**30 DAE**	**45 DAE**	**60 DAE**	**75DAE**
$N_1 \times S_1$	0.13e	2.7bcd	2.27d	3.98b	4.98cd
$N_1 \times S_2$	0.30ab	2.89abcd	3.72ab	4.488ab	6.07ab
$N_1 \times S_3$	0.15de	2.72abcd	2.43d	3.82b	5.03cd
$N_2 \times S_1$	0.17de	2.16d	2.60d	3.87b	4.75d
$N_2 \times S_2$	0.24bc	3.03ab	3.89ab	4.39ab	6.01abc
$N_2 \times S_3$	0.15de	2.25cd	3.31bc	3.65b	4.71d
$N_3 \times S_1$	0.27abc	2.64bcd	2.77cd	5.07ab	6.59a
$N_3 \times S_2$	0.32a	3.13ab	4.26a	5.22ab	6.5a
$N_3 \times S_3$	0.27abc	2.76abcd	3.94ab	6.05a	5.09bcd
$N_4 \times S_1$	0.31a	3.19ab	2.82cd	5.39ab	6.19a
$N_4 \times S_2$	0.26abc	3.39a	4.05ab	4.52ab	6.61a
$N_4 \times S_3$	0.21cd	2.92abc	3.60ab	4.24ab	4.73d
$LSD_{(0.05)}$	0.068	0.74	0.76	1.93	1.09
CV (%)	13.15	13.94	9.85	25.92	9.83

In a column means having similar letter(s) are statistically similar and those having dis-similar letter(s) differ significantly as per 0.05 level of probability

Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

S_1=20 cm×5cm S_2=30cm×5cm S_3=40cm×5cm

4.2 Effect on yield parameters and yield

4.2.1 Number of siliquae plant^{-1}

Application of nitrogen fertilizer treatments significantly influenced the number of siliquae plant^{-1} (Table 4).

Table 4. Effect of nitrogen levels and row spacing on siliquae plant^{-1}, length of siliqua, seeds siliqua^{-1} and 1000-seed weight of mustard

Treatments	Siliquae plant^{-1} (no.)	Length of siliqua(cm)	Seeds siliqua^{-1}(no.)	1000-seed weight (g)
Nitrogen levels				
N_1	68.44 b	5.19b	14.78ab	3.32b
N_2	67.89b	5.31b	13.67b	3.44ab
N_3	90.78a	6.73a	17.0a	3.45ab
N_4	76.67b	5.17b	15.56ab	3.81a
LSD $_{(0.05)}$	11.25	0.58	2.91	0.57
CV (%)	12.84	8.92	16.56	7.65
Row spacing				
S_1	70.75 b	5.07b	14.58b	2.99c
S_2	92.2a	6.34a	17.33a	4.05a
S_3	64.67b	5.39b	13.83b	3.47b
LSD $_{(0.05)}$	11.39	0.35	2.35	1.23
CV (%)	17.34	7.20	17.82	21.46

In a column means having similar letter(s) similar and are statistically those having dis-similar letter(s) differ significantly as per 0.05 level of probability

Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

S_1=20 cm×5cm S_2=30cm×5cm S_3=40cm×5cm

The result revealed that the highest number of siliquae plant^{-1} (90.78) was obtained from N_3 (115 kg ha^{-1} N application) treatment which was different from other treatments.

The lowest result was found with N_2 treatment (67.89) which was similar to N_1 (68.44) and N_4 (76.67) (Table 4).

Table 5. Interaction effect of nitrogen levels and row spacing on siliquae plant^{-1}, length of siliqua, seeds siliqua^{-1} and 1000-seed weight of mustard

Treatments	Siliquae plant^{-1} (no.)	Length of siliqua (cm)	Seeds siliqua^{1} (no.)	1000- seed weight (g)
$N_1 \times S_1$	61.67e	4.5f	15.0b	2.83cd
$N_1 \times S_2$	74.0cde	6.43abc	16.0ab	3.78abc
$N_1 \times S_3$	69.67de	4.63f	13.33bc	3.36abcd
$N_2 \times S_1$	62.67de	4.57f	15.33ab	2.88cd
$N_2 \times S_2$	80.0bcd	5.7cd	16.0ab	4.13ab
$N_2 \times S_3$	57.0e	5.50de	9.67c	3.29bcd
$N_3 \times S_1$	95.33abc	6.8ab	14.67b	2.75d
$N_3 \times S_2$	105.33ab	7.0a	20.0a	4.04ab
$N_3 \times S_3$	71.67de	6.abc	16.33ab	3.55abcd
$N_4 \times S_1$	63.33de	4.4f	13.33bc	3.5abcd
$N_4 \times S_2$	106.33a	6.06bcd	17.33ab	4.27a
$N_4 \times S_3$	60.33e	5.03ef	16.0ab	3.66abcd
$LSD_{(0.05)}$	21.7	0.81	4.81	1.83
CV (%)	17.34	7.20	17.82	21.46

In a column means having similar letter(s) are statistically similar and those having dis-similar letter(s) differ significantly as per 0.05 level of probability

Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

S_1=20 cm×5cm S_2=30cm×5cm S_3=40cm×5cm

Row spacing had significant influence on number of siliquae plant^{-1} (Table 4). The highest value was (92.42) obtained with 30 cm row spacing (S_2) was significantly different from that of S_1 and S_3. The lowest number of siliquae plant^{-1} (64.67) was recorded in S_3 (30 cm row spacing) and was statistically similar to that of S_1 (70.75).

The interaction effect was best with $N_4 \times S_2$ treatment (106.33) which were statistically similar to $N_3 \times S_1$ (95.33) and $N_3 \times S_2$ (105.33).The lowest value came from $N_2 \times S_3$ treatment (57.0) which were statistically similar (Table 5). From the result it was seen that increasing application of N fertilizer increase number of siliquae plant^{-1} and recommended spacing provided the best result.

4.2.2 Length of siliqua(cm)

Nitrogen levels also influenced significantly the length of siliquae (Table 4). The F_3 treatment had the highest value (6.73 cm) in case of length of siliqua where other treatments were more or less similar. The lowest value of length of siliqua as recorded in F_4 treatment (5.17 cm), which was statistically similar to that of F_1 (5.19 cm) and F_2 (5.31cm).

Length of siliqua was also significantly influenced by row spacing. The highest length of siliqua (6.34 cm) was recorded by S_2 treatment, whereas it was lowest in S_1 (5.07 cm) and was statistically similar to that of S_3 treatment (5.39 cm) (Table 4).

Interaction effect of nitrogen levels and row spacing on length of siliqua was also significant (Table 5). $N_3\times S_2$ treatment provided the highest value (7.0 cm) and $N_4\times S_1$ treatment had the lowest (4.4 cm) result which was statistically similar to $N_1\times S_1$, $N_2\times S_1$ and $N_1\times S_3$.

4.2.3 Number of seeds siliqua^{-1}

Number of seeds siliqua^{-1} was significantly influenced by different nitrogen levels (Table 4). The highest number of seeds siliqua^{-1} (17.00) was found in N_3 treatment and was statistically similar to that of N_4 (15.56) and N_1 (14.78). The lowest number of seeds siliqua^{-1} was recorded in N_2 (1.67) treatment.

There were significant differences in number of seeds siliqua^{-1} due to different row spacing (Table 4). The number of seeds siliqua^{-1} was the highest (17.33) in S_2 (30 cm row spacing) treatment. It was the lowest recorded (13.83) in S_3 (40 cm row spacing) and was statistically similar (14.58) to that of S_1 (20 cm row spacing) treatment.

The interaction effect of nitrogen levels and row spacing on number of seeds siliqua^{-1} was found significant (Table.5). $N_3\times S_2$ treatment combination produced the highest (20.0) number of seeds siliqua^{-1} and was statistically similar to that of all other treatment combinations except $N_1\times S_1$, $N_1\times S_3$, $N_3\times S_1$ and $N_4\times S_1$. The lowest combination of number of seeds siliqua^{-1} was recorded in $N_2\times S_3$ (9.67). Similar result were also reported by Sharawat *et al*. (2002), Sen *et al*. (1977) and Allen and Morgan (1972).

4.2.4 1000-seed weight

Nitrogen levels had the significant influence on 1000-seed weight of mustard (Table 4). The highest 1000-seed weight (3.81g) was found in N_4 treatment and was statistically similar to that of N_3 (3.45 g) and N_2 (3.44 g). The lowest value (3.32 g) was found in N_1 treatment and was also statistically similar to that of N_2 and N_3 but significantly different from that of N_4 treatment.

Row spacing had also statistically significant influence on 1000-seed weight (Table 4). The highest 1000-seed weight (4.05 g) was recorded in S_2 (30 cm row spacing) treatment and was significantly different from that of S_3 (40 cm row spacing) and S_1 (20 cm row spacing) treatments. The lowest 1000-seed weight (2.99g) was found in S_1 treatment and was significantly different from that of all other treatments.

The interaction effect of nitrogen levels and row spacing on 1000-seed weight was also significant (Table 5). The highest 1000-seed weight was found in the interaction of $N_4 \times S_2$ (4.27 g) and was statistically identical to that of all other treatment combinations except that of $N_1 \times S_2$, $N_2 \times S_3$, $N_1 \times S_1$ and $N_3 \times S_1$. The treatment combination $N_3 \times S_1$ showed the lowest 1000-seed weight (2.75 g).

4.2.5 Seed yield (kg ha^{-1})

There were significant differences in seed yield due to nitrogen levels (Table 6).The highest value of seed yield (156.85 kg ha^{-1}) was found in N_3 treatment which was significantly different from that of all other treatments. The lowest value of harvest indeed yield was found in N_4 (72.70 kg ha^{-1}) and was statistically similar to that of N_1 (80.73kg ha^{-1}) and N_2 (99.16kg ha^{-1})

Row spacing also had significant influence on seed yield (Table 6). The highest seed yield (136.4 kg ha^{-1}) was found in S_2 treatment, which was significantly different from that of S_1 (81.43 kg ha^{-1}) and S_3 (81.91 kg ha^{-1}). The lowest seed yield was found in S_1 and it was similar to that of S_3.

The interaction effect of nitrogen levels and row spacing was significant for seed yield of mustard (Table 7). The highest seed yield (216.28 kg ha^{-1}) was found in the interaction of $N_3 \times S_2$, which was significantly different from that of all other treatment combinations. The lowest seed yield (52.34 kg ha^{-1}) was found in $N_4 \times S_3$ combination, which was statistically similar to that of $n_1 \times S_1$ and $N_2 \times S_3$ and significantly different from that of all other treatment combinations.

Table 6. Effect of nitrogen levels and row spacing on stover yield, seed yield and harvest index of mustard

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
Nitrogen levels			
N_1	957.8ab	966.7ab	55.23a
N_2	855.6b	1311.1ab	63.49a
N_3	1211.1a	1443.3a	67.62a
N_4	871.1b	1113.3b	57.03a
$LSD_{(0.05)}$	322.26	452.22	NS
CV (%)	28.69	32.44	22.7
Row spacing			
S_1	954.2a	1140.8a	58.30a
S_2	1060.8a	1341.7a	63.85a
S_3	906.7a	1143.3a	60.38a
$LSD_{(0.05)}$	NS	NS	NS
CV (%)	22.38	24.30	17.31

In a column means having similar letter(s) are statistically similar and those having dis-similar letter(s) differ significantly as per 0.05 level of probability

Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138kg ha^{-1}

S_1=20 cm×5cm S_2=30cm×5cm S_3=40cm×5cm

Table 7. Interaction effect of nitrogen levels and row spacing on seed yield, stover yield and harvest index of mustard

Treatments	Seed Yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
$N_1 \times S_1$	896.7bc	776.7c	55.83a-c
$N_1 \times S_2$	926.7bc	1043.0bc	47.3c
$N_1 \times S_3$	1050.0a-c	1080.0bc	62.57a-c
$N_2 \times S_1$	916.7bc	1433.3ab	58.93a-c
$N_2 \times S_2$	906.7bc	1290.0bc	71.73a
$N_2 \times S_3$	743.3c	1210.0bc	59.8a-c
$N_3 \times S_1$	1230.0ab	1240.0bc	65.57a-c
$N_3 \times S_2$	1393.3a	1946.7a	67.67a-c
$N_3 \times S_3$	1010.0bc	1143.3bc	69.63ab
$N_4 \times S_1$	773.3c	1113.3bc	52.87a-c
$N_4 \times S_2$	1016.7a-c	1086.7b	68.7ab
$N_4 \times S_3$	823.3bc	1140.0bc	49.53bc
$LSD_{(0.05)}$	21.13	70.05	21.34
CV (%)	19.96	25.75	17.31

In a column means having similar letter(s) are statistically identical and those having dis-similar letter(s) differ significantly as per 0.05 level of probability

Here, N_1= 69 kg ha^{-1} N_2=92 kg ha^{-1} N_3=115 kg ha^{-1} N_4=138 kg ha^{-1}

S_1=20 cm×5cm S_2=30cm×5cm S_3=40cm×5cm

4.2.6 Stover yield (kg ha^{-1})

The stover yield of mustard was significantly influenced by nitrogen levels (Table 6).The highest stover yield was found in N_3 (75.11 kg ha^{-1}) and was statistically identical to that of N_1, whereas significantly different from that of N_2 and N_4. The lowest stover yield was found in N_4 (54.78 kg ha^{-1}) and was statistically similar to that of N_2 (57.00 kg ha^{-1}).

Row spacing had significant effect on stover yield of mustard (Table.6) .The highest stover yield (77.25 kg ha^{-1})was recorded in S_2 and significantly different from that of S_3 and S_1. The lowest value was recorded in S_3 (53.75 kg ha^{-1}) and was statistically similar to that of S_1 (5.25 kg ha^{-1}) treatment.

The interaction effect of nitrogen levels and row spacing was also found significant for stover yield of mustard (Table 7). The interaction of $N_3 \times S_2$ combination produced the highest stover yield (103.33 kg ha^{-1}) and was statistically similar to that of $N_1 \times S_2$ interaction, whereas significantly different from that of all other treatment combinations. The lowest stover yield (46.00 kg ha^{-1}) was recorded in the combination of $N_2 \times S_3$ was statistically similar to that of all treatment combinations except $N_3 \times S_2$ and $N_1 \times S_2$.

4.2.7 Harvest Index (%)

There were significance differences among the harvest index due to nitrogen levels (Table 6).The highest value of harvest index (67.62%) was found in N_3 treatment which was statistically similar to that of N_2 (63.49%) treatment. The lowest value of harvest index was found in N_1 (55.23%) and as statistically similar to that of N_4 (57.03%) and significantly different from that of all other treatments.

Row spacing also had significant influence on harvest index (Table 6). The highest harvest index (63.85%) was found in S_2, was statistically similar to that of S_3 (60.38%) and significantly different from that of S_1 (58.30%).

The interaction effect of nitrogen levels and row spacing was significant for harvest index of mustard (Table 7). The highest harvest index (71.73%) was found in the interaction of $N_2 \times S_2$, which was statistically similar to that of all other treatment combinations except that of $N_1 \times S_2$. The lowest value of harvest index was found in $N_1 \times S_2$ combination and was statistically similar to that of all other treatment combinations except that of $N_3 \times S_3$, $N_4 \times S_2$ and $N_2 \times S_2$.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University farm, Dhaka during the period from November 2015 to February 2016 to study the effect of different nitrogen levels and row spacing on growth and yield of rapeseed. The experimental site was located at 23°74'N latitude and 90°35' E longitude at an altitude of 8.6 meter and belongs to the agro-ecological zone 28 (Madhupur Tract).

The experiment was consisted of two treatment factors; factor A: 4 levels of nitrogen (N_1=69 kg ha^{-1}, N_2=92 kg ha^{-1}, N_3=115 kg ha^{-1} and N_4=138 kg ha^{-1}) and factor B: 3 levels of row spacing (S_1=20 cm×5cm, S_2=30cm×5cm and S_3=40cm×5cm). The experiment was laid-out in split-pot design with three replications assigning nitrogen levels in the main plot and row spacing in the sub plot. The land was prepared well by ploughing and cross-ploughing with a tractor-drawn plough followed by laddering. Seeds were sown on 7 November, 2015. The land was fertilized withP_2O_5 (TSP), K_2O (MoP), gypsum, Zinc sulphate and Borax @ 81, 51, 27, 3.9 and 1 kg ha^{-1}, respectively and urea was applied as per treatment. The data on plant height, total dry matter $plant^{-1}$ at 15, 30, 45, 60 and 75 days after emergence (DAE), yield parameters and yields were recorded.

Nitrogen level, row spacing and their interaction influenced significantly the plant height, number of branches plant^{-1}, dry matter plant^{-1}, yield parameters, stover yield ,seed yield and harvest index of rapeseed.

At all the growth stages, the plant height, number of branches plant^{-1}, dry matter plant^{-1} increased with the increasing rate of nitrogen level up to 138 kg ha^{-1}, thereafter declined. At maturity, the number of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1}, seed yield, stover yield and harvest index were the highest (90.78, 6.73 cm, 17.0, 1211.1kg ha^{-1}, 1443.3kg ha^{-1} and 67.62%, respectively) in N_3, whereas the highest 1000-seed weight (3.81g) was found in N_4. The lowest values for these parameters were found respectively in N_2, N_1, N_2, $N_{4,}$ $N_{4,}$ N_1 and N_1 treatments.

At all the growth stages, the plant height, number of branches plant^{-1}, dry matter plant^{-1} were the highest in S_2 (30cm row spacing). The lowest values for these parameters were found in S_3 (40 cm row spacing) at all growth stages except 45 DAE for number of branches plant^{-1} and dry matter plant^{-1}. At 45 DAE the lowest values for these parameters were found in S_1 (20 cm row spacing). The highest value for number of siliquae plant^{-1}(92.42), length of siliquae (6.34 cm), 1000-seed weight (4.05 g), stover yield(1341.7kg ha^{-1}), seed yield (1060.8 kg ha^{-1}) and harvest index (63.85%) were found in S_2 (30 cm row spacing), whereas the lowest values for these parameters were found respectively in S_1 except number of siliquae plant^{-1} and seed yield. The lowest values for these two parameters were found in S_3 treatment.

At all growth stages $N_3\times S_2$ showed the highest plant height, whereas the differential effects of treatment combinations were found at different growth stages for number of branches plant^{-1} and dry matter plant^{-1}. The interaction of $N_3\times S_2$ produced the highest length of siliqua(7.0 cm), number of seeds siliqua^{-1} (20.0), stover yield (1946.7 kg ha^{-1}) and seed yield (1393.3kg). The lowest seed yield (774.3kg ha^{-1}) was found in $N_2\times S_3$.

Considering the above findings it may be concluded that the performance of SAU Sharisha-3 was better in respect of growth, yield and yield components with combined application of N_3 (115 kg ha^{-1}) and S_2 (30 cm row spacing).

To arrive at sound conclusion, it is recommended to do further experimentation with these combinations of nitrogen levels and row spacing on rapeseed in the potential production areas of Bangladesh.

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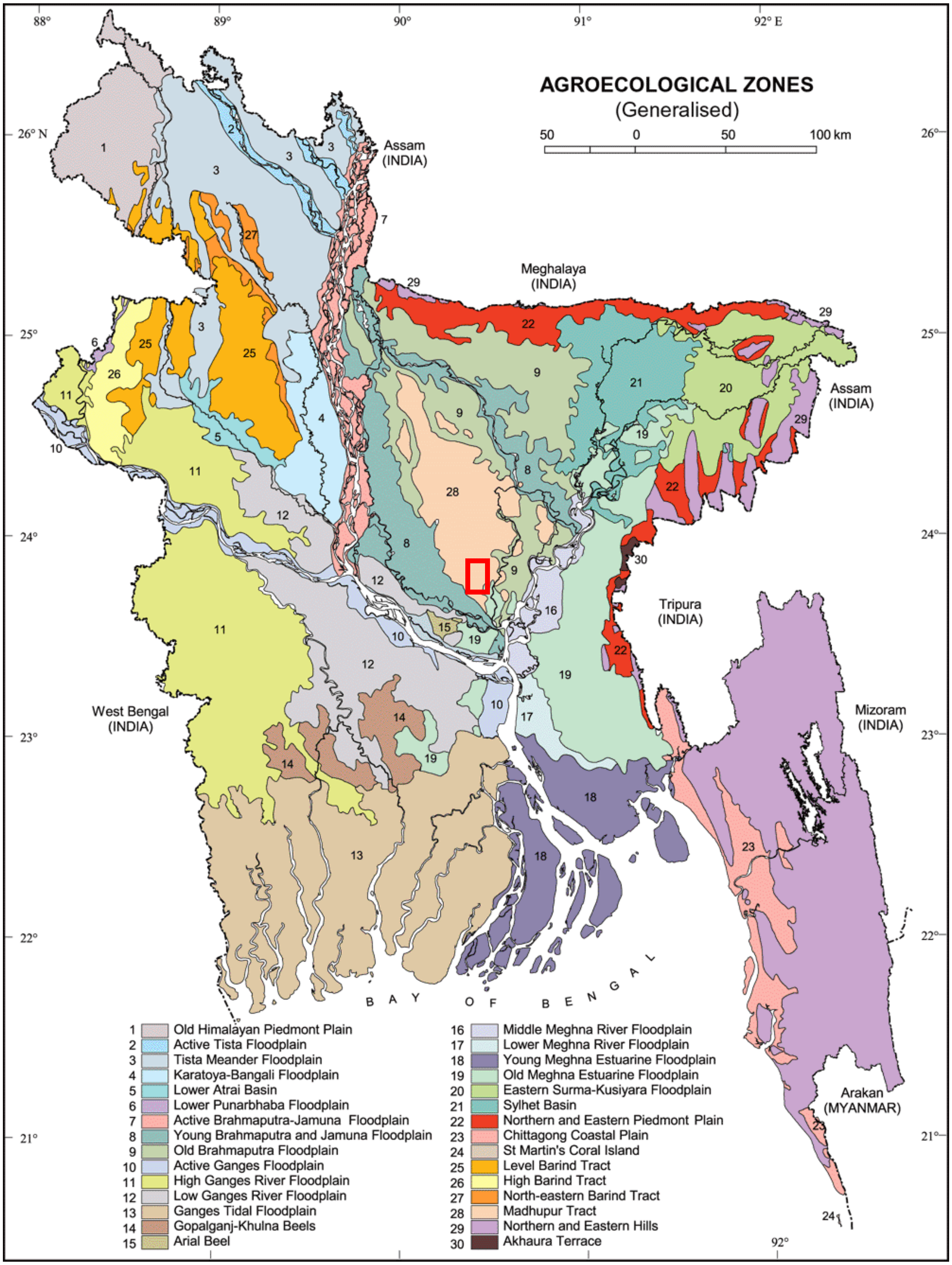
APPENDICES

Appendix I. The map of experimental site



Appendix II. Layout of experimental site

Appendix III. Monthly average air temperature, relative humidity, total rainfall and sun shine hours of the experimental site during November'15- February'16

Month	Air Temperature(°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2015	28.10	6.88	58.18	1.56	5.8
December, 2015	25.36	5.21	54.30	0.63	7.9
January, 2016	21.17	15.46	64.02	0.00	3.9
February, 2016	24.30	19.12	53.07	2.34	5.7

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1207.

Appendix IV. Physical characteristics of the soil

CHARACTERISTICS	**Value**
Sand (%) (0.2-0.02 min)	10
Silt (%) (0.02-0.002 min)	60
Clay (%) (<0.002 min)	30
Soil textural class	Silty clay loam
Particle density (g/cc)	2.60
Bulk density (g/cc)	1.35
Porosity(%)	46.67

Appendix V. Chemical properties of the soil of experiment field before seed sowing

CHARACTERISTICS	VALUE
pH	5.70
Organic matter (%)	2.35
Total N (%)	0.12
K (mg/100 g soil)	0.17
P (Mg/g soil)	8.90
S (Mg/g soil)	30.55
B (Mg/g soil)	0.62
Fe (Mg/g soil)	310.40
Zn (Mg/g soil)	4.82

Source: Soil Resource Development Institute (SRDI), Krishi Khamar Sharak, Dhaka.

Appendix VI. Analysis of variance of the data of plant height of mustard as influenced by nitrogen and row spacing

Source of variation	Degrees of freedom	Mean Square of				
		15 DAE	30 DAE	45DAE	60DAE	75DAE
Replication	2	1.74	9.15	8.48	1.64	37.48
Nitrogen(A)	3	43.29*	72.32*	261.22*	324.94*	224.74*
Error 1	6	2.46	24.49	28.81	54.08	50.37
Row Spacing(B)	2	120.84*	674.64*	420.91*	673.57*	495.6*
Interaction A× B	6	4.32*	17.59*	16.81*	28.88*	79.3*
Error 2	16	1.43	14.41	30.26	18.65	21.23

* : Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of number of branches plant^{-1} of mustard as influenced by nitrogen and row spacing

Source of variation	Degrees of freedom	Mean Square		
		45 DAE	**60 DAE**	**75DAE**
Replication	2	0.33	0.03	0.36
Nitrogen(A)	3	2.44	1.95	5.33*
Error 1	6	0.33	0.89	1.25
Row Spacing(B)	2	5.26*	6.33*	28.78*
Interaction A× B	6	0.92	0.81	1.33
Error 2	16	0.75	0.74	0.65

* : Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of dry matter weight plant^{-1}of mustard as influenced by nitrogen and row spacing

Source of variation	Degrees of free-dom	Mean Square				
		15 DAE	30DAE	45DAE	60DAE	75DAE
Replication	2	0.00324	0.28180	0.68610	1.44602	0.32405
Nitrogen(A)	3	0.02243	0.75192	1.22076	4.13289*	1.58687
Error 1	6	0.00207	0.18564	0.28024	0.71234	0.45271
Row Spac-ing(B)	2	0.02308	0.89689	5.61903*	0.13610	5.93389*
Interaction A× B	6	0.00649	0.09717	0.18741	0.85698	0.63259
Error 2	16	0.00093	0.15203	0.10596	1.39589	0.30355

* : Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of number of siliquae plant^{-1}, length of siliqua, seeds siliqua^{-1} and 1000-seed weight of mustard as influenced by nitrogen and row spacing

Source of variation	Degrees of freedom	Mean Square			
		siliquae plant^{-1}	length of siliqua	seeds siliqua^{-1}	1000-seed weight
Replication	2	164.78	0.08567	11.0833	2.08017
Nitrogen(A)	3	1025.07*	5.17697*	17.6574*	0.88952
Error 1	6	95.07	0.24963	6.3796	0.29085
Row Spacing(B)	2	2553.03*	5.26009*	40.7500*	0.41977
Interaction A× B	6	352.10*	0.65994	11.9352*	0.18610
Error 2	16	173.37	0.16239	7.3889	0.56600

* : Significant at 0.05 level of probability

Appendix X.Analysis of variance of the data of stover yield, seed yield and harvest index of mustard as influenced by nitrogen and row spacing

Treatment	Degrees of freedom	Mean square		
		Stover yield(kgha^{-1})	Seed yield (kgha^{-1})	Harvest index(%)
Replication	2	23553	7719	263.383
Nitrogen(A)	3	399647*	243300*	359.314*
Error 1	6	153697	78053*	193.086
Row spacing(B)	2	159353*	74803	137.285*
Interaction(A×B)	6	180153*	44658	179.174*
Error 2	16	86249	47490	112.211

* : Significant at 0.05 level of probability

APPENDIX II: Layout of experimental site

Factor A : Nitrogen levels

F_1 =150 kg ha^{-1}

F_2 =200 kg ha^{-1}

F_3 =250 kg ha^{-1}

F_4 =300 kg ha^{-1}

Factor B : Row spacing

S_1= 20cm×5cm

S_2= 30cm×5cm

S_3= 40cm×5cm