MORPHOLOGY YIELD AND SEED QUALITY OF RAPESEED (*Brassica campestris* L.) AS INFLUENCED BY NITROGEN AND ZINC

BY

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CERTIFICATE

This is to certify that thesis entitled, "**Morphology Yield and Seed Quality of Rapeseed (*Brassica campestris* L.) as Influenced By Nitrogen and Zinc**" submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, embodies the result of a piece of bona fide research work carried out by **Tahmina Akter Rimi, Registration No. 06-01971** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was undertaken during rabi season, November 2011 to February 2012 to examine the response of different levels of nitrogen and zinc application on morphology yield and seed quality of rapeseed (*Brassica campestris* L.) variety BARI Sarisha 15. In this experiment, the treatment consisted of four different N levels *viz.* N_0 = 0 kg N/ha, N_1 = 60 kg N/ha, N_2 = 120 kg N/ha and N_3= 180 kg N/ha, and three different level of Zn *viz.* Zn_0 = 0 kg/ha, Zn_1= 1 kg Zn/ha, Zn_2 =2 kg Zn/ha. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Results of the experiment showed a significant variation among the treatments in respect of the majority of the observed parameters. The 120 kg N/ha resulted the highest plant height, number of leaves per plant, number of branches per plant, length of inflorescence, number of siliquae per plant, seed weight of hundred siliquae, thousand seed weight. The maximum yield of seed per hectare (3.57 t) was obtained from 120 kg N/ha. The maximum number of siliquae per plant, seed weight of hundred siliquae, thousand seed weight, seed yield (3.31 t/ha) was recorded with 2 kg Zn/ha. Separately, application of Zn did not show significant difference on morphological parameters such as plant height, number of leaves per plant and length of inflorescence as N. In addition, oil content of rapeseed varied significantly with both N and Zn independently whereas germination percent had no effect with either N or Zn. These results indicated that N has role on both vegetative and reproductive phases but Zn only on reproductive phase. The interaction between different levels of N and Zn was significantly influenced on almost all morphological parameters and yield contributing characters, seed yield and oil content. The maximum value of morphological parameters, yield contributing characters, seed yield of rapeseed was observed with the combined dose of 120 kg N/ha along with 2 Kg Zn/ha whereas the lowest values were obtained from control, 0 kg N/ha and 0 kg Zn/ha treatment combination. The maximum yield of seed per hectare (4.22 tones) and the maximum oil content (43.29%) was obtained from 120 kg N/ha with 2 Kg Zn/ha treatment combination. Based on the present results, it can be suggested that the combined use of 120 kg N/ha with 2 kg Zn/ha increased plant morphological parameters, seed yield and oil content of rapeseed.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
Zn	=	Zinc
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muirate of Potash
RCBD	=	Randomized Complete Block Design
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

Chapter I

INTRODUCTION

Rapeseed (*Brassica campestris* L.) is a bright yellow flowering member of the family Brassicaceae. It is originated from Asia minor and known as an oil yielding crop in Canada, Australia, China, India and other countries in the world including Bangladesh. It has been grown by humans for around thousands of years and is of the few edible oilseeds capable of being grown in cool temperate climates. Cabbage, broccoli, brussels sprouts, cauliflower etc is also close to both rapeseed in view of morphology and physiology. It is well known that rapeseed is popular for crop rotations, since it enhances yields of wheat and barley, and breaks disease cycles in cereal grains.

Rapeseed oil is one of the most important edible oils contain 40-45% oil from them 33% oil may be extartecd using ghani and 20-25% protein and plays a vital role in human diet (Mondal and Wahhab, 2001). Its nutritive value is excellent due to the abundant unsaturated fatty acids. It is not only rich source of energy (about 9 k cal/g) but also rich in soluble vitamins A, D, E and K. Rapeseeds or mustard seeds are an excellent source of essential vitamins B-complex such as folates, niacin, thiamin, riboflavin, pyridoxine (vitaminB-6), pantothenic acid. The B-complex groups of vitamins help in enzyme synthesis, nervous system function and regulating body metabolism. These vitamins are essential in the sense that body requires them from external sources to replenish. The National Nutrition Council of Bangladesh (NNC) reported that recommended dietary allowance (RDA) per capita per day should be 6 g of oil for a diet with 2700 K cal. On RDA basis, the edible oil need for 150 millions peoples are 0.39 million tons of oil equivalent to 0.82 million tons of oilseed (NNC, 1984). Rapeseed contains more phenolic compounds, sinapic acid and its derivatives, most notable sinapine than any other oilseed plant (Nowak *et al.* 1992) which has potential value in the regulation of low density lipoprotein (LDL), cholesterol oxidation as a biomarker for cardiovascular diseases (DiSilvestro, 2001 and Halliwell, 1995) and suggesting that phenolics are functional food element that intended for health benefit. The aroma and pungent flavor of mustard comes from secondary metabolite, glucosinolate which is hydrolyzed by myrosinase to produce isothiocyanate that can inhibit weed seed germination during crop production. It has been also reported that 100 g of mustards provide 4.733 mg of niacin, vitamin B 3 which is a part of nicotinamide co-enzymes; helps regulate blood cholesterol and triglyceride levels in human body. Oil cake is a nutritious food item for cattle and fish and also used as a good organic fertilizer. Dry mustard plants may be used as fuel. This information is suggesting that mustard has diversified functions in a both agriculture and human physiology.

It is well known that rapeseed is one the major oilseed crop in Bangladesh and covering about 70% of the total production. The area and production of mustard in this country was about 0.481 million hectares and 0.536 million tons, respectively with an average yield of 1.11 t ha^{-1} during 2010-2011 (AIS, 2012). The present domestic edible oilseed production is 267 thousand tons, which meets only one third of national oil demand. So, Bangladesh had to import a large quantity of edible oil every year at the cost of huge amount of foreign exchange worth BDT 11000 million during 2005-2006 fiscal years (BBS, 2006). The growth and seed yield of rapeseed is not to desired levels due to the imbalance use of nutrients, inefficiency to select a suitable variety, lack of high yielding (HYV) seed, lack of knowledge on climate change and lack of suitable approaches. In the meantime, the scientists have developed some varieties to increase the yield and quality of rapeseed. In addition, several researchers are still working for improving the morphological characters, seed yield and oil content of rapeseed with several crop management practices along with proper combination of macro and micro nutrients.

Many previous reports showed that fertilization is the depending source of nutrient that can be used to boost up growth and yield of crops (Sinha *et al*., 2003; Shukla *et al*., 2002a; Meena *et al*., 2002 and Zhao *et al*., 1997). Nitrogen (N) has an important role in seed protein and physiological functions of the plant and supports the plant with rapid growth, increasing seed and fruit production and enhancing quality of leaf and oil seed yield (Allen and Morgan 2009). Mondal and Gaffer (1983) reported that N has significant effect on plant height, branches $plant^{-1}$, siliquae $plant^{-1}$ and other growth factors and yield of mustard. In addition, the N significantly increased morphophysiological parameters such as leaf area and rate of photosynthesis etc. Many authors showed that the use of N @ 250 kg/ha and @180 kg/ha produced higher seed yield (Hossain and Gaffer 1997 and Singh and Prosad 2003). High yielding varieties of rapeseed are very responsive to fertilizers especially N (Ali and Rahman, 1986; Sharawat *et al*., 2002 and Patel *et al*., 2004). Separately, N increases the vegetative growth but delayed maturity of seed yielding plants and excessive use of this element may produce too much of vegetative growth, thus food production may be impaired and suggesting that N management is crucial in cropping system and for normal plant growth and development (Maini *et al.*, 1959 and Singh *et al.*, 1972). These results suggest that the optimum doses of N/ha for rapeseed seed yield is needed to verify.

Micronutrients play an important role in plant system for proper growth and development. Zinc (Zn) is essential trace element for proteins synthesis and amino acids accumulation in plant tissues, protein synthesis decline by Zn deficit in plants indicates that Zn is the main composition of ribosome. One of the sites of protein synthesis is pollen tube that amount of Zn in there tip is 150 $\mu g g^{-1}$ of dry matter and this Zn will contribute on the pollination by impact on pollen tube formation (Marschner, 1995; Outten *et al.*, 2001 and Pandey *et al.*, 2006). In addition, seedlings from seeds containing high zinc have better ability to withstand adverse environmental conditions. It was also reported that Zn is the active element in biochemical processes and has a chemical and biological interaction with some other elements. Applying Zn to plants grown under potentially Zn-deficient soils is effective in reducing uptake and accumulation of phosphorus in plants (Mirvat *et al.*, 2006 and Cakmak, 2008). Micronutrient, Zinc (Zn) increased mustard seed yield and oil content by developing root system and increasing leaf area to stimulate tryptophan, precursor of Indole acetic acid (IAA), promoting photosynthesis. It has been also reported that pollen sterility was recorded in low Zn condition thus reduces the seed yield. In addition, Zn has a protective role against oxidative damage (Arvind and Prasad, 2005). Furthermore, zinc may be required for chlorophyll production, pollen function and fertilization and zinc deficiency also affects carbohydrate metabolism, damages pollen structure, and decreases the yield (Pandey *et al.*, 2006). However, little is known whether Zn regulates plant architecture, seed yield, oil content, and germination percent of rapeseed.

Application of proper amount of both macro and micro nutrients is essential to maximize crop production in soil or without soil. The N and Zn fertilizer play a vital role in enhancing the production of mustard and thereby reducing the oil deficit in the country. The deficiency of N is widespread in Bangladesh due to high cropping intensity, lack of use of organic matter into soil, reduction of livestock production, use of hybrid varieties for increasing yield etc. Zhu *et al.* (1996) reported that Zn increased the mustard seed yield 18% over NPK alone. Both Zn deficiency and excessive N decreased the oil content in mustard. It is become evident that without the use of micronutrient, it is not possible to get the maximum benefits of NPK fertilizers and high yielding varieties of seed plants. In Bangladesh, there is limited information on the combined use of N and Zn on growth and yield of oil producing *Brassica spp*. However, to my knowledge little is known whether different doses of N along with different doses of Zn regulate the growth, yield and oil content of rapeseed using new variety of BARI Sarisha 15 which is moderately salinity resistant. In view of above points a field experiment containing the treatments of N and Zn was conducted with the following objectives:

- To analyze the independent effects of N and Zn on the morphological characters, yield and oil content of rapeseed variety BARI sarisha 15.
- To investigate the interaction effects of N and Zn on morphological characters, yield and oil content of rapeseed variety BARI sarisha 15.
- To find out the best combination of N and Zn for better seed yield and oil content of rapeseed variety BARI sarisha 15.

Chapter II

REVIEW OF LITERATURE

Among the oilseed crops, rapeseed occupies the top most position in Bangladesh. The proper fertilizer management essentially influences it's morphological characters and yield performance. Experimental evidences showed that there is a profound influence of nitrogen (N) and zinc (Zn) fertilizers on this crop. A brief of the relevant works performed in the past are presented in this Chapter

2.1 Effect of nitrogen (N) on morphological parameters, seed yield and oil content of rapeseed:

A field experiment was carried out by Mozaffari *et al.* (2012) at Qazvin-Iran during 2009-2010 to assess the effect of different levels of nitrogen at the rate of (0, 75, 150 and 225 kg ha-1) and potassium (0, 45, 90 and 135 kg ha-1) on yield and some of the agronomical characteristics in Rapeseed (*Brassica juncea*). The results showed that increased amount of nitrogen and Potassium up to 225 kg N ha-1 and 135 kg K ha-1 respectively had a positive and significant ($p<0.01$) effect on thousand seed weight (TSW), seed yield (SY) and seed oil yield (SOY).

A field experiment was conducted by Gupta *et al.* (2011) during the rabi season of 2003-2004 and 2004-2005. They reported from their field experiment that higher dose of nitrogen 120 kg N/ha produced maximum oil yield.

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

A field experiment was conducted by 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) on the growth, yield and quality of Indian Rapeseed cv. GM-2. In combination treatments, 3 irrigation + N at 100 kg/ha + 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.

A field experiment was conducted by Sinsinwar *et al.* (2004) during the 1999/2000 and 2000/01 rabi seasons in Bharatpur, Rajsthan, India to determine the best cropping sequence and N fertilizer application rate (0, 30, 60 and 90 kg/ha) of Indian Rapeseed cv. RH-30 under brackish water situation. 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 Rapeseed significantly increased with each increment of N fertilizer up to 60 kg/ha, 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, respectively. The Indian Rapeseed seed equivalent yield was significantly highest in pearl millet + black gram followed by Indian Rapeseed (3190 kg/ha) cropping sequence during 1999/2000. In 2000/01, the Indian Rapeseed equivalent yield of pearl millet + black gram followed by Indian Rapeseed was highest (2435 kg/ha).

Meena and Sumeriya (2003) carried out a study to evaluate the effect of nitrogen (0, 30, 60 and 90 kg/ha) on oil content of Rapeseed (*Brassica juncea*). Application of 60 kg N/ha gave the maximum oil content (37.04%) compared to no nitrogen application.

Abadi *et al.* (2001) also indicated that N had a significant effect on oil content of rapeseed and Rapeseed.

Field experiments were conducted by 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 Rapeseed cv. Pusa Jai Kisan (V1) and rape cv. Pusa Gold (V2). The treatments comprised: Ti (S0:N50 + 50); T2 (S40:N50 + 50 for V1 and S40:N50+25 + 25 for V2); and T3 (S20 + 20:N50 + 50 for V1 and S20 + 10 + 10:N50 + 25 + 25 for V2). Split application of S and N (T3) resulted in a significant increase 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 for V1 and 3.06 t/ha for V2 under T3. The average oil yield under T3 was 1.71 t/ha for V1 and 1.42 t/ha in V2. The oil and protein contents in the seeds of V1 and V2 also increased with the split application of S and N. It may be concluded from these results that the yield and quality of rapeseed-Rapeseed can be optimized with the split application of 40 kg S/ha and 100 kg N/ha during the appropriate phenological stages of crop growth and development.

Khan *et al.* (2003) observed that cycocel at 400 ppm + 60 kg N/ha and ethrel at 200 ppm + 80 kg N/ha 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.

Kader *et al.* (2003) observed that the effects of row spacing (30, 45 or 60 cm) and N rate (60, 120 or 180 kg/ha) on the yield of Indian Rapeseed cv. Basanti were studied. N was applied at sowing (50%) and after the initial irrigation (50%). They found among the N rates, 120 kg/ha gave the highest seed yield (20.24 quintal/ha), straw yield (12.22 quintal/ha), stick yield (43.52 quintal/ha), and net profit (12975 rupees/ha). The highest cost benefit ratio (0.85) was obtained with 180 kg N/ha.

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

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

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

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

Singh P.C. (2002) also reported that plant height increased significantly with successive increase in nitrogen up to 120 kg/ha.

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

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

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

An experiment was conducted by Tripathi A. K. and Tripathi, H. N. (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) on the growth, yield and quality of Indian Rapeseed cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and at 60 days after sowing.

Babu and Sarkar (2002) reported that rapeseed cultivars responded to N application up to 80 kg ha^{-1} Dry matter yield, N content, N uptake and percent of N by Rapeseed cultivars significantly increased with an increase in the level of fertilizer N. Percent of N significantly increased from 12 at 40 kg N ha^{-1} to 22 at 80 kg N ha^{-1} in rapeseed yield while in stover the corresponding values ranged from 11 to 20%. Successive levels of N also increased significantly the uptake of soil N by Rapeseed 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 registered significantly higher seed and stover yield of Rapeseed over control and 30 kg N/ha and found statistically at par with 90 kg N/ha.

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 siliquae (15.3), 1000-seed weight (5.85 g), and seed yields (1649, 2217, and 1261 kg/ha).

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 resulted in the highest number of siliquae per plant (397 25), weight of siliquae per plant (33 32 g), number of seeds per siliquae (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%).

Singh (2002) found that application of N and P increased the length of siliquae, number of siliquae per plant, seeds per siliquae, seed yield and 1000-seed weight of Rapeseed. However, the significant increase in yield and yield components was recorded in 60, 90 and 120 kg N/ha and 30, 45 and 60 kg P/ha treatments. The maximum seed yield was recorded from application of 45 kg P/ha (11.43 and 13.85 q/ha in 1999 and 2000, respectively) and 120 kg N/ha (12.98 and 13.83 q/ha in 1999 and 2000, respectively). The oil content also increased with the application of N and P, but was not significant

Shukla *et al.* (2002b) conducted an experiment to observe the effect of nitrogen for Indian Rapeseed (*B. juncea*). They found that maximum number of siliquae per plant, maximum siliquae length, maximum number of seeds per siliquae, maximum 1000-seed weight and maximum seed yield per hectare was obtained with the application of 120kg N/ha. They also reported that growth characters and length of siliquae increased significantly with successive increase in nitrogen up to 120 kg/ha.

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

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

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

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

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

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

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

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

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 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.

Hossain and Gaffer (1997) conducted an experiment with 5 levels of nitrogen viz. 0, 100, 150, 200, 250 kg/ha on rapeseed and maximum yield was found 1,73 t/ha with 250 kg N/ha.

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

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

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, but 1000 seed weight and number of seeds siliqua remained unchanged. The cv. Varuna was found to be highest yielding cultivar.

Mondal *et al.* (1996) reported that the highest seed yield of rapeseed (1.40 t/ha) was obtained from fertiflzer levels of 150:90:100:30:4:1 kg/ha of N, P_2O_5, K_2O, S, Zn and B along with 6 tones cowdung.

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 incieasing 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.

Shahidullah *et al.* (1996) observed in a fertilizer trial with 0, 75, 100 and 150 kg ha 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.

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.

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

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

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

Khanpara *et al.* (1992) in a field experiment on clay loam soil with Rapeseed (*B. juncea*) observed that the level of 60 kg N ha^{-1} was significantly superior to other levels for seed yield, plant height and primary and secondary branches $plant^{-1}$.

Islam *et al.*, (1992) from their field trail at Mymensingh found increased seed yield of Rapeseed cv. Sambal from 0.73 to + 1.91 t ha^{-1} with 0-200 kg N ha^{-1} applied at the different stages of the growth.

Rana *et al.* (1991) reported that nitrogen application at the rate of 0, 50, 100, 150 kg ha^{-1} increased yield gradually and it reached maximum by N application up to 100 kg ha^{-1}.

Tomer and Mishra (1991) observed that N application increased seed yield of Rapeseed (*B. Juncea.*) from 0-32 to 1.12 ton ha^{-1}. Singh and Chauhan (1991) found a field trials that application of 60 kg N ha^{-1} as urea to Rapeseed resulted in higher seed yield (1.53 t ha^{-1}) than that of 30 kg N applied as urea.

Ali *et al.* (1990) obtained higher seed yield of rapeseed when 90 kg N ha^{-1} was applied under rainfed condition.

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

Sharma and Kumar (1990) observed that application of 120 kg N ha^{-1} increased the seed yield of Rapeseed 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.

Murtuza 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) bserved 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 $plant^{-1}$.

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

Sounda *et al.* (1989) reported from a two years trial under rainfed condition with Rapeseed (*B. juncea*) that increasing rates (0-90 kg ha^{-1}) of nitrogen increased seed yield from 245 to 628 kg ha^{-1} in one year and also from 277 to 778 kg ha^{-1} in another year.

Shrivastava *et al.* (1988) observed in an experiment conducted with musrard (*Brassica juncea* cv. varuna) that the application of nitrogen at the rate of 90 kg/ha at the preflowering stage gave highest harvest index.

Hasan and Rahman (1987) showed that application of nitrogen at the rate of 120 Kg ha^{-1} increased the plant height, number of pod in the primary branches and in the main racemes and seed yield of Rapeseed. *B. campestris* cv. Kalayania with nitrogen up to 120 kg ha^{-1} gave highest plant height, seed, stover and biological yield, while 60 kg N ha^{-1} resulted the highest number of primary branches, siliqua, seed weight $plant^{-1}$ and 1000-seed weight.

Shamsuddin *et al.* (1987) working with Rapeseed with five levels of nitrogen (0,30, 60, 90 and 120 kg N /ha) 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 nitrogen. Nitrogen at the rate of 120 kg /ha gave taller plant, highest no of primary branches per plant (5.3) and the highest seed yield (830 kg /ha) over control. Thousand seed weight also increased significantly due to application of nitrogen.

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

Singh and Singh (1987) stated that increasing rate of nitrogen from 75 kg /ha applied to Rapeseed (*Brassica juncea*) increased the seed yield from 1.20-1.33 to 2.11-2 14 t/ha.

Narang and Singh (1985) fertilized Indian Rapeseed with four levels of nitrogen (viz. 0, 50, 100 and 150 kg /ha). They have observed that nitrogen at the rate of 150 kg /ha gave highest seed yield (1.8 t /ha) over control.

Nitrogen is an essential macronutrient. High yielding mutants / varieties of Rapeseed are very responsive to nitrogen (Ali and Rahman, 1986 and Gupta *et al.*1985). Nitrogen is essentials for cell division and expansion, chloroplast development, chlorophyll concentration and enzyme activity (Gardner *et al.*1985).

Mondal and Gaffer (1983) working with rapeseed give five levels of nitrogen viz. 0, 35, 105 and 140 kg/ha observed that different levels of nitrogen had significant effects on the plant height, number of primary branches/plant, number of filled siliquae/plant, number of seeds/siliquae, weight of seed/plant, weight of total dry plant/plot and yield of seeds over control. They further, observed that plant height, number of primary branches/plant and number of filled siliqua/plant were increased with the increasing doses of nitrogen. Nitrogen at the rate of 140 kg/ha produced highest number of fertile seeds/siliquae and seed yield (1.3 t/ha).

Patel *et al.* (1980) performed a field experiment with four levels of nitrogen (viz. 0, 25, 50 and 75 kg /ha). They reported that different levels of nitrogen gave different seed yields of Rapeseed significantly. The highest seed yield was 0 73 t /ha achieved at the rate of 50 kg N /ha due to the formation of higher no. of secondary branches /plant, higher no. of siliquae /plant and higher harvest index.

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

2.2 Effect of zinc (Zn) on morphological parameters, seed yield and oil content of rapeseed:

Dubey *et al.* (2013) conducted an experiment during the rabi season of 2008-09 in RBD and replicated three times. The sowing was done on November 20, 2008. The treatments comprised four levels of sulphur (0, 20, 40 and 60 kg S ha^{-1}) and four levels of zinc (0, 5, 7.5 and 10 kg Zn ha^{-1}). The Rapeseed variety "Varuna" was used as test crop. Application of 60 kg S ha^{-1} and 10 kg Zn ha^{-1}, produced significantly higher plant, primary and secondary branches $plant^{-1}$, number of leaves $plant^{-1}$, days taken to flowering, days taken to maturity, number of siliqua $plant^{-1}$, length of siliqua, and number of seeds $siliqua^{-1}$, harvest index and oil content. However, dry matte accumulation $plant^{-1}$, 1000-grain weight (g), biological yield, seed yield, stover yield and protein content significantly increased with increasing dose of sulphur up to 40 kg and zinc 7.5 kg ha^{-1}. The highest benefit cost ratio (1.68) was obtained with treatment combination $S_{40}Z_{7.5}$. The interaction effect of sulphur and zinc levels on various parameters of Rapeseed was found non-significant.

Ismail and Theodor (2013) studied is to examine the impact of the heavy metals Zinc and Nickel as oxidative stressfactors on antioxidative enzymes, which are known to be important defense system of plants to metal stress, superoxide dismutase(SOD), catalase (CAT) and guiacol peroxidase (GPOD) activities of 8 weeks old hairy root cultures of *Brassica juncea* L.czern and the increased activity of antioxidative enzymes in metal stressed hairy roots appears to serve as an important component of antioxidant defense mechanism of hairy roots of indian Rapeseed to combat metal induced oxidative injury. In this study, the results demonstarted that metal induced oxidative stress occurs in hairy roots of *Brassica juncea* L.czern.(indian Rapeseed) even though the growth of hairy roots is enhanced or unaffected by the presence of heavy metals. Enhanced activities of SOD, CAT and GPOD was observed in hairy roots at high concentrations of Zinc and Nickel and there was no increase in the activities of these three antioxidative enzymes while in low concentrations of these two metals.

Zinc is essential micronutrients for proteins production in plants; also zinc is main composition of ribosome and is essential for their development. Zinc is active element in biochemical processes and has a chemical and biological interaction with some other elements. Phosphorus is the most important element which interferes on zinc uptake by plants. Phosphorus is the important element that interferes on zinc uptake, as zinc uptake by plants reduces by increasing phosphorus in soil. High levels of phosphorus may decrease the availability of zinc or the onset of zinc deficiency associated with phosphorus fertilization may be due to plant physiological factors. Higher concentrations of copper in the soil solution, relative to zinc, can reduce the availability of zinc to a plant (and vice versa) due to competition for the same sites for absorption into the plant root. This could occur after the application of a copper fertilizer. Zinc deficiency is lead to iron (Fe) deficiency, due to prevent of transfer of Fe from root to shoot in zinc deficiency conditions. Sufficient amount of zinc in the plant improve the harmful effects of boron (B) deficiency. Zinc deficiency decreases plant growing by increasing the concentration of boron in the young leaves and tips of the branches (Mousav *et al.* 2012).

Nawaz *et al.* (2012) conducted on a sandy clay loam soil at the National Agricultural Research Centre, Islamabad, Pakistan, during 2005 and 2006. The Rapeseed (*Brassica juncea*) variety BARD-1 was treated with various -1 levels of Zn and Fe, (0-0, 0-1.5, 0-3, 2.5-0, 2.5-1.5, 2.5-3, 5-0, 5-1.5 kg/ha and -1 -1 5-3 kg/ha), respectively. A basal dose of 90N and 60P kg ha was applied, in the form of Urea and triple super phosphate (TSP) with Zn and Fe. The increase in -1 Zn and Fe fertility from 0-1.5 to 5-1.5 kg ha increased yield of BARD-1. The maximum yield response was recorded when 5 kg ha Zn and 1.5 kg ha Fe were applied. Beyond this level, no further increase in yield was recorded in any Rapeseed traits. A positive correlation was recorded between seed yield and 1000-seed weight with the application of 5 kg Zn ha and 1.5 kg Fe ha in combination at the time of sowing. It can therefore be concluded that 100 % seed yield of Rapeseed variety BARD-1 increased at 5 Zn: 1.5 Fe kg ha as a result of increased pods plant , number of seeds pod and 1000-seed weight.

Aye (2011) conducted to find out the effect of biofertilizer formulated with four species of bacteria (two species of Azotobacter and two species of Lysobacter) and zinc sulphate. Field experiments with Rapeseed plant were conducted to study the effectiveness of soil application of zinc sulphate and biofertilizer at 0, 10, 20, 30, 40, 50 days after sowing. Plant height and condition of plant was found to be increased significantly using a mixture of biofertilizer and zinc sulphate than other treatments after 40 days sowing. Three treatments were also used in this field experiment such as bacteria only, zinc sulphate only and mixture of biofertilizer and zinc sulphate. The treatment using a mixture of zinc sulphate and biofertilizer had the best yield (4688.008 kg/ha) within 50 days of sowing and performed better than other treatments. Field experiment using zinc sulphate only was second best yield (3380.75Kg/ha) and biofertilizer only treatment gave (2639.04kg/ha).

Nabi *et al.* (2011) application of S,P and Zn to a soil of Nabipur series (Typic Camborthids) significantly ($P<0.05$) increased dry matter yield of brassica grown in pots. There was no interactive effect of these elements on dry matter yield. Sulphur, P and Zn application had significant main and all first order interactive affects on S concentration as well as total S contents in plants. Only S and P had a significant main effect on concentration and uptake of P by plants. Also significant main and first order interactive influence of S and P application on concentration and total content of Zn in plants has been discussed.

Yasari and Patwardhan (2006) conducted for investigating the impacts of chemical nutrients on canola (*Brassica napus* L.) seed yield and quality (oil, protein and nutrients concentration). Application of N P K together with S, and Zn, singly or in combination, improved the yield and the quality of the seed. The maximum yield (3141.250 kg/h) and oil content (45.83 %) were obtained at Tip (NPK, Zn), coinciding with 203 pods/plant and 120.53 cm plant height. The application of NPK, S at T9 resulted not only in the maximum seed protein (24.25 %) and N concentration in the seed (3.88 %) but also in highest concentration of P (0.257 %), K (1.853 %) and S (130 ppm) in the leaves at flowering. The maximum N concentration happened with NPK at T8 (3.85 %) while the maximum Zn concentration obtained with NPKZn at T10(27.17 ppm). The P, K, S and Zn concentrations in the seed were maximum at T7 (0.69 %), T7.10 (0.66 %) T9 (0 37 %) and at T10 (55.03 ppm), respectively, showing substantial improvements over the control.

Krishna *et al.* (2006) conducted to study the effect of P, S and Zn on quality characteristics of Rapeseed. It was observed that oil, glucosinolate and protein contents were higher at 60 kg each of phosphorus and sulphur and 30kg $ZnSO_4$/ha during both the years. On contrary, oil constants I.e. refractive index, Iodine value and acid value were reduced due to application of P, 5 and Zn during both the years.

Among the micronutrients, Zn deficiency is most widespread on a wide range of soils in cold and warm climates (Cakmak *et al.* 1996). The role of Zn in subsoil nutrition is particular interesting because of its importance in maintaining membrane integrity of root cells (Welch 1995). In rapeseed, root growth was impaired and seed yield was severely depressed when Zn was omitted from the subsoil (Grewal *et al.* 1997). The aim of this study was to evaluate the effects of foliar Zn application on yield, yield components, oil and protein percentage in seeds of rapeseed.

Positive interactions of zinc and organic manure were observed by numerous scientists particularly in cereal crops. Patel *et al.* (2008) observed that combined use of 5 t FYM and 16 kg $ZnSO_4$ ha-1 every year resulted in the highest maize straw and grain yields, and Zn content and uptake in both grain and straw. The highest net returns were also obtained with 5 t ha-1 FYM + 16 kg ZnSO4 ha-1. Similarly, use of FYM significantly improved Zn concentration and uptake in plants, while available N, P, K and Zn contents of soil were also enhanced.

Zinc is among those minerals that were first considered as essential for plants, animals and human (Welch, 1995). Deficiency of Zn is a wide-spread nutrient disorder in several crops. Abundance of free carbonates, organic matter shortage and alkaline pH of soil are the main causes of Zn deficiency in crops. Zinc deficiency is more severe in rain-fed soil than in irrigated areas, as some nutrients are supplemented in soil with irrigation water.

Chapter III

MATERIALS AND METHODS

The experiment was undertaken during rabi season, November 2011 to February 2012 to examine the response to different levels of nitrogen (N) and zinc (Zn) on morphology, yield, yield attributes and seed quality of rapeseed variety BARI Sarisha 15.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at $90^{0}22^{'}$ E longitude and 23°41′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28.

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.4 Materials

3.4.1 Seed

A moderately salinity tolerant and high yielding variety of rapeseed, BARI Sarisha 15 developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and was used as an experimental material. The seed was collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing of the seed in the experimental plot, germination test was done in the laboratory and results of percentage of germination was over 95%.

3.4.2 Fertilizers

The recommended doses of Triple super phosphate (TSP) as a source of phosphorus (P), Muriate of Potash (MP) as a source of Potash (K), Gypsum as a source of Sulpher (S) and Boric acid as a source of Boron (B) were added to the soil of experimental field along with different levels of Nitrogen (N) in the form of Urea and Zinc (Zn) in the form of Zinc Oxide (ZnO) according to the treatment of the experiment.

3.5 Methods

3.5.1 Treatments

Factor A: 4 levels of N (kg/ha)

N_0 = 0 kg N/ha

N_1 = 60 kg N/ha

N_2 = 120 kg N/ha

N_3= 180 kg N/ha

Factor B: 3 level of Zn (kg/ha)

Zn_0 = 0 (kg/ha)

Zn_1= 1 kg Zn/ha

Zn_2 =2 kg Zn/ha

3.5.2 Treatment combinations

There are 12 treatment combinations of different N and Zn doses used in the experiment under as following:

1. N_0Zn_0
2. N_0Zn_1
3. N_0Zn_2
4. N_1Zn_0
5. N_1Zn_1
6. N_1Zn_2
7. N_2Zn_0
8. N_2Zn_1
9. N_2Zn_2
10. N_3Zn_0
11. N_3Zn_1
12. N_3Zn_2

3.5.3 Design and layout

The experiment consisted of 12 treatment combinations and was laid out Randomized Complete Block Design (RCBD) with 3 replications. The total plot number was $12 \times 3 = 36$. The unit plot size was $3\ m \times 1.5\ m = 4.5\ m^2$. The distance between blocks was 1 m and distance between plots was 0.5 m and plant spacing was 30 cm × 5 cm. The layout of the experiment is presented in Appendix II.

3.5.4 Land preparation

The land was ploughed with a rotary plough and power tiller for four times. Ploughed soil was then brought into desirable fine tilth and leveled by laddering. The weeds were clean properly. The final ploughing and land preparation were done on 15 November, 2011. According to the lay out of the experiment the entire experimental area was devided into blocks and prepared the experimental plot for the sowing of rape seed. In addition, irrigation and drainage channels were made around the plot.

3.5.5 Fertilization

In this experiment fertilizers were used according to Bangladesh Agricultural Reserch Institute (BARI) Information which is given under as follows:

Name of Nutrients	Name of Fertilizers	Rate of Application (kg/ha)
Nitrogen (N)	Urea,	As per treatment
Phosphorus (P)	Triple Super Phosphate	160
Potash (K)	Muriate of Potash	110
Sulpher (S)	Gypsum	160
Boron (B)	Boric acid	7.5
Zinc (Zn)	Zinc Oxide	As per treatment

The amounts of fertilizer as per treatment in the forms of urea, triple super phosphate, muriate of potash, gypsum, boric acid and zinc oxide required per plot were calculated. The triple super phosphate, muriate of potash, gypsum, boric acid was applied during final land preparation. Half of urea and total amount of Zn was also applied in each experimental unit plot according to treatment combination and incorporated into soil before sowing seed. Rest of the urea was top dressed after 30 days of sowing (DAS).

3.5.6 Sowing of seed

Sowing was done on 17 November, 2011 in rows 30 cm apart. Seeds were sown continuously in rows at a rate of 8 kg/ha. After sowing, the seeds were covered with the soil and slightly pressed by hand, and applied little amount water for better germination of seeds.

3.5.7 Thinning and weeding

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

3.5.8 Irrigation

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

3.5.9 Crop protection

As a preventive measure of aphid infestation, Malathion 57 EC @ 2 ml $litre^{-1}$ of water was applied twice first at 25 DAS and second at 50 DAS.

3.5.10 General observation of the experimental field

The field was investigated frequently in order to reduce losses with weeds competition and insects infestation and diseases infection.

3.5.11 Harvesting and threshing

Previous randomly selected ten plants, those were considered for the growth analysis was collected from each plot to analyze the yield and yield contributing characters. Rest of the crops was harvested when 80% of the siliquae in terminal raceme turned creamy white in color. After collecting sample plants, harvesting was started on February 15 and completed on February 20, 2012. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated from the plants by beating the bundles with bamboo sticks.

3.5.12 Drying and weighing

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

3.6 Data collection

Ten (10) plants from each plot were selected as random and were tagged for the data collection. Some data were collected from sowing to harvesting with 10 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm)
2. No. of leaves plant^{-1}
3. No. of primary branches plant^{-1}
4. Length of main inflorescence (cm)
5. No. of siliquae on the main inflorescence
6. Seed weight of 100 siliquae
7. Seed weight plot^{-1}
8. Seed weight of thousand siliquae (g)
9. Yield (t/ha)
10. Harvest index (%)
11. Seed oil content (%)
12. Germination percentage of seed (%)

3.6.1 Plant height (cm)

Plant height was measured five times at 10 days interval such as 20, 30, 40,50 and 60 DAS. The height of the plant was measured by scale considering the distance from the soil surface to the tip of the randomly ten selected plants and mean value was calculated for each treatment.

3.6.2 Number of leaves plant^{-1}

Number of leaves per plant was counted five times at 10 days interval such as 20, 30, 40, 50 and 60 DAS of rapeseed plants. Mean value of data were calculated and recorded.

3.6.3 Number of primary branches plant^{-1}

The number of primary branches per plant was counted five times at 10 days interval such as 20, 30, 40, 50 and 60 DAS of rapeseed plants. Mean value of data were calculated and recorded.

3.6.4 Length of main inflorescence(cm)

The length of main inflorescence of ten plants was measured from the base of the inflorescence to the tip of the main inflorescence with measuring scale. Mean length of main inflorescence was calculated and expressed in cm.

3.6.5 Number of siliquae on the main inflorescence

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

3.6.6 Seed weight of hundred siliquae (g)

A composite sample was taken from the yield of ten plants. The seed weight of hundred siliquae of each plot were counted and weighted with a digital electric balance. The seed weight of hundred siliquae was recorded in g.

3.6.7 Seed weight per plot (g)

Total mustard plants were collected from each plot .The plants were cut, threshed and dried. The dried seeds were weighed.Then the weighed seed yield was converted to kg.

3.6.8 Thousand seed weight (g)

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

3.6.9 Yield (t/ha)

After threshing, cleaning and drying, total seed from harvested area were recorded and was converted to t/ ha.

3.6.10 Harvest index (%)

Harvest index was calculated by dividing the economic seed yield from the net plot by the total biological yield of seed and stover from the same area and multiplying by 100.

3.6.11 Seed oil content (%)

The oil content of seed was determined from Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, and Gazipur- 1701. Oil content of seeds was determined by the following methods of Mehlenbacher (1960). The principle of this methods lies in mixing the sample with a solvent, petroleum ether (BP.40 to 60^{o}C), which was then removed by distillation and the residue was dried and weighed. The extraction procedure was carried out in soxhlet apparatus. The oil content of seed was calculated by following formula

$$\text{Percentage of oil content} = (W_1 \times 100) / W$$

Where,

W = Weight of the sample, and

W_1 = Weight of the ether extract

3.6.12 Germination percentage of seed

The germination percentage of seed was analyzed from Seed Certification Agency (SCA), Joydebpur, Gazipur. The germination percentage of seed was determined in

$$\frac{\textit{Total no.of seed germinated}}{\textit{Total no.of seed}} \times 100$$

3.7 Data analysis

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

Chapter IV

RESULTS AND DISCUSSION

The results obtained with different levels of nitrogen (N) and zinc (Zn) and their combination are presented and discussed in this chapter. Data about morphological parameters, yield contributing characters, seed yield and oil content of rapeseed have been presented in both Tables and Figures and analyzes of variance and corresponding degrees of freedom have been shown in Appendix.

4.1 Plant height

The results of this study showed that nitrogen (N) levels showed significant effect on rapeseed plant height as dose dependent manner at different days after sowing (DAS) (Fig. 1 and Appendix III). The plant height increased with increasing the age of the plants. The tallest plant height (28.9, 34.9, 81.2, 94.0 and 95.8 cm at 20, 30, 40, 50 and 60 DAS respectively) was recorded with N_2, 120 kg N ha^{-1}. In contrast, the smallest plants were recorded from control, N_0 at 20, 30, 40, 50, 60 DAS and height was 23.5, 26.9, 71.6, 84.2 and 86.2 cm, respectively. The N fertilizer's requirements can differ very much according to soil type, climate, management practice, timing of nitrogen application, cultivars, etc. These findings are in agreement with those of Singh *et al.* (2003), Tripathi and Tripathi (2003), Singh *et al.* (2002). Similar findings were reported by Tomar *et al.* (1996), FAO (1999), Ali and Ullah (1995), Shamsuddin *et al.* (1987), Ali and Rahman (1986) and Hassan and Rahman (1987). All together, these results suggest that higher doses of N increase rapeseed plant height at different DAS.

Data pertaining to Fig. 2 and Appendix III revealed that plant height was not significantly affected by different doses of Zn at DAS. However, plant height increased with increasing levels of Zn up to higher level. The tallest plant (27.3, 34.1, 79.4, 91.4 and 83.6 cm at 20, 30, 40, 50 and 60 DAS, respectively) was produced with Zn_2, 2 kg Zn/ha and shortest plant (26.6, 30.5, 73.8, 89.4 and 91.2 cm at 20, 30, 40, 50 and 60 DAS, respectively) was found in no Zn condition. These results suggest that Zn has no

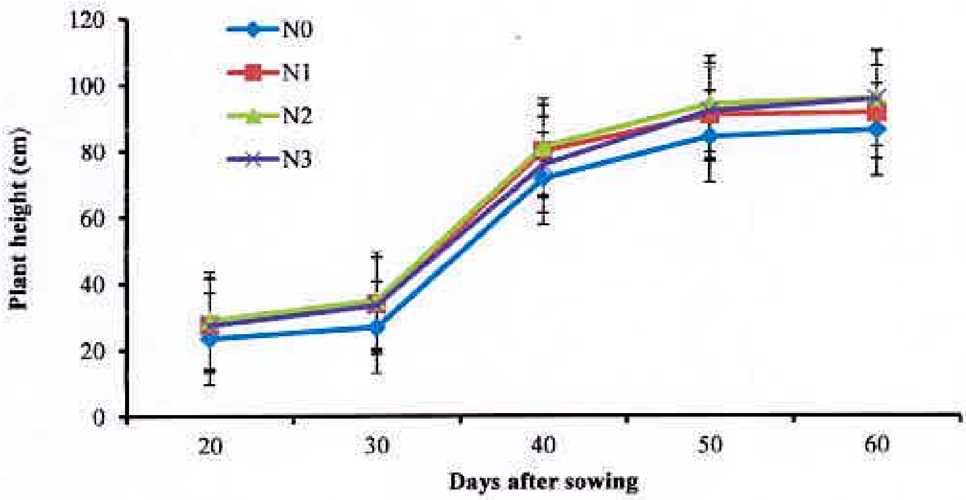

Fig. 1: Effect of different levels of nitrogen at different DAS on the height of rapeseed plant (DAS = Days after sowing, N_0 = without nitrogen, N_1 = 60 kg N /ha, N_2 = 120 kg N/ha, N_3 = 180 kg N/ha, Error bars represent standard error).

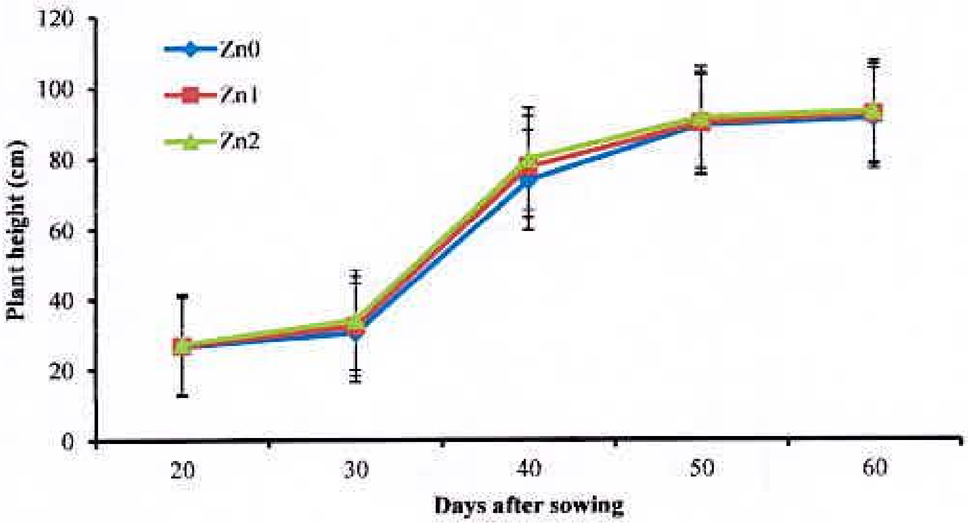

Fig. 2: Effect of different levels of zinc at different DAS on the height of rapeseed plant (DAS = Days after sowing, Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha, Error bars represent standard error).

contribution to elongate of the axis of the plant during growth period.

The plant height of rapeseed significantly increased with the by the interaction between N and Zn (Table 1 and Appendix III). The tallest plant height (30.1, 37.3, 84.3, 96.1, and 98.5 cm at 20, 30, 40, 50 and 60 DAS, respectively) was found in N_2Zn_2 treatment combination, 120 kg N/ha with 2 kg Zn/ha whereas the shortest plant (22.7, 25.4, 68.7, 82.9, and 84.3cm at 20, 30, 40, 50 and 60 DAS, respectively) was observed in the control treatment combination (Plate 1 and 2). Singh P.C. (2002) reported that plant height increased significantly with successive increase in nitrogen up to 120 kg/ha. The N increased plant height but Zn could not show any effect on plant height of rapeseed separately. All together these results indicate that plant height of rapeseed increase with combined use of N and Zn.

4.2 Number of leaves plant^{-1}

The N showed significant variation in the number of leaves per plant at 20, 30, 40, 50 and 60 DAS (Fig. 3 and Appendix IV). The maximum number of leaves per plant (5.59, 8.56, 12.9, 29.7 and 30.2 at 20, 30, 40, 50 and 60 DAS, respectively) was produced by 120 kg N/ha and without N produced the lowest number of leaves per plant (5.22, 7.44, 9.00, 18.2 and 19.2 at 20, 30, 40, 50 and 60 DAS, respectively). It is reported that better growth and development of crop depend on a good number of leaves and producing more foliage related to the yield of rapeseed (through higher siliquae yield and stover yield) to the seed production those are linked to use of amount of N fertilizer and suggesting that the greater number of leaf, the greater the photosynthetic area which may result higher seed yield. These indicate number of leaves per plant increased with increasing N levels; those are consistent with Patil *et al.* (1997) findings.

Number of leaves per plant due to the influence of Zn was not significant at 20, 30, 40, 50 and 60 DAS (Fig. 4 and Appendix IV). With the 2 kg Zn/ha had the highest number of leaves per plant (5.50, 8.25, 24.8 and 26.6 cm at 20, 30, 40, and 50 DAS, respectively). However, the lowest number of leaves per plant (5.13, 7.92, 10.8, 25.3 and 25.8 at 20, 30, 40, 50 and 60 DAS, respectively) was obtained from the control. So, Zn has important role on increasing number of rapeseed leaves.

Table 1: Interaction effect of nitrogen (N) and zinc (Zn) on the height of rapeseed plant at different days after sowing (DAS)

Treatments	Plant height (cm)									
	20 DAS		30 DAS		40 DAS		50 DAS		60 DAS	
N_0Zn_0	22.7	e	25.4	f	68.7	g	82.9	f	84.3	c
N_0Zn_1	23.4	de	25.5	f	69.4	g	85.1	ef	87.9	abc
N_0Zn_2	24.4	d	29.6	e	74.6	ef	84.5	ef	85.9	abc
N_1Zn_0	27.7	bc	36.5	ab	82.1	abc	93.1	abc	94.8	abc
N_1Zn_1	27.7	bc	32.3	d	78.3	b-e	91.6	bcd	93.6	abc
N_1Zn_2	27.5	bc	36.1	ab	83.1	ab	94.4	ab	95.3	abc
N_2Zn_0	28.0	bc	32.4	d	76.3	de	88.1	de	84.7	bc
N_2Zn_1	28.9	ab	32.4	d	78.9	bcde	91.1	bcd	95.4	abc
N_2Zn_2	30.1	a	37.3	a	84.3	a	96.1	a	98.5	a
N_3Zn_0	27.9	bc	35.1	bc	81.3	abcd	92.4	abc	97.2	ab
N_3Zn_1	26.9	c	31.7	d	70.9	fg	89.7	cd	92.6	abc
N_3Zn_2	27.2	bc	33.6	cd	77.4	cde	93.7	abc	96.8	abc
LSD $_{(0.05)}$	1.57		1.94		4.84		3.66		11.0	
Significant level	*		*		*		*		*	
CV (%)	3.45		13.2		9.00		7.41		7.05	

In a column treatments having similar letter(s) do not differ significantly as per LSD

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

Plate 1. Photograph shows the rapeseed grown with N_2Zn_2 treatment combination (120 kg N/ha and 2 kg Zn/ha).

Plate 2. Photograph shows the rapeseed grown with N_0Zn_0 treatment combination (without N and Zn).

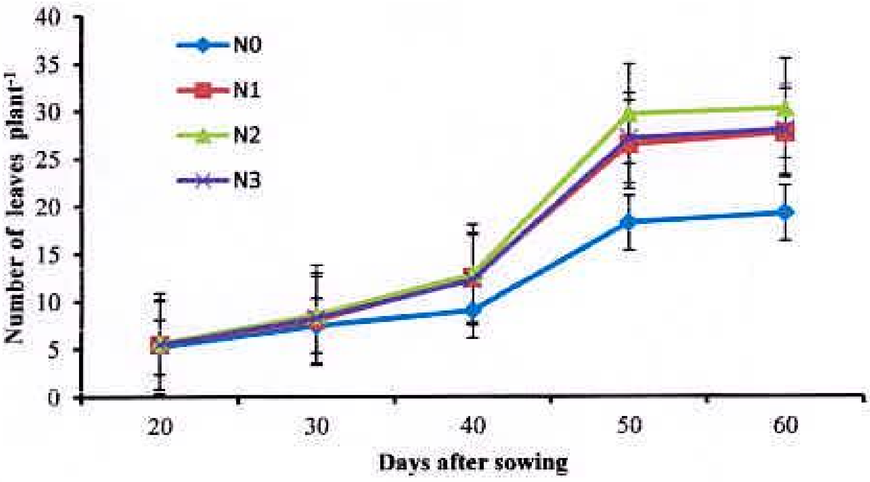

Fig. 3: Effect of nitrogen at different DAS on the number of leaves plant^{-1} of rapeseed (DAS = Days after sowing, N_0 = without nitrogen, N_1 = 60 kg N/ha, N_2 = 120 kg N/ha , N_3 = 180 kg N/ha, Error bars represent standard error).

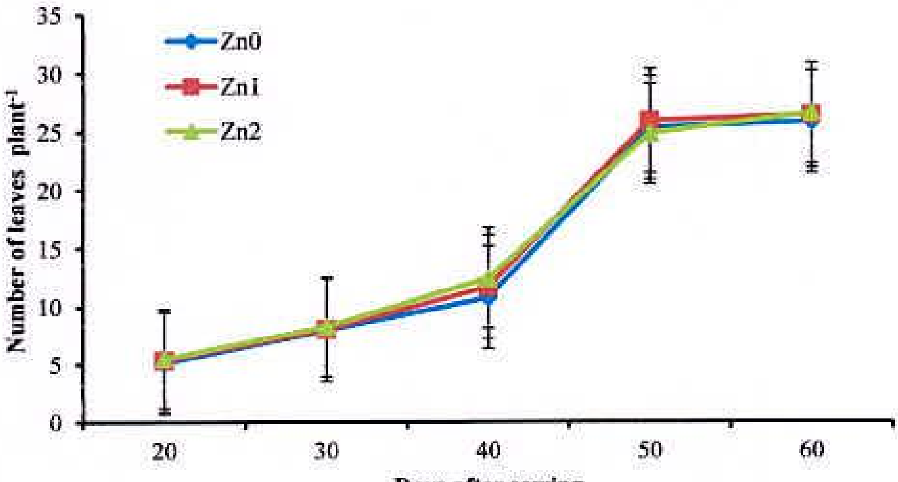

Fig. 4: Effect of different doses of zinc at different DAS on the number of leaves per plant of rapeseed (DAS = Days after sowing, Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha, Error bars represent standard error).

A significant variation in the number of leaves per plant was found between the N and Zn (Table 2, Appendix IV). The maximum number of leaves per plant (5.67, 9.33, 16.0, 32.3 and 32.7 at 20, 30, 40, 50 and 60 DAS, respectively) was found in combined use of 120 kg/ N and 2 kg Zn/ha, N_2Zn_2 treatment, whereas the lowest number of leaves per plant (5.00, 7.00, 8.33, 16.7 and 18.7 at 20, 30, 40, 50 and 60 DAS, respectively) was found in control treatment. It is well established that mineral nutrition influences plant growth and absorption of elements, proper N application enhance Zn accumulation in plants which trigger both vegetative growth and reproductive development (Hemlin and Barker, 2003). The result of leaves number plant^{-1} of this study is consistent with the plant height (Table 1) and suggesting that combined use of N and Zn increase rapeseed canopy structure.

4.3 Number of Primary branches plant^{-1}

The Figure 5, Appendix 5 showed that different levels of N had significant effect on number of primary branches per plant. The maximum number of branches per plant (6.56) was produced by 120 kg N/ha. Control produced the minimum number of branches per plant (3.89). Tomar *et al.* (1991, 1996), Ali and Ullah (1995) also obtained highest number of branch per plant with 120 kg N ha^{-1}. In contrast, Mondal and Gaffer (1983) also reported that N fertilizer application had no significant effect on number of primary branches per plant of rapeseed. Altogether, it suggests that N involve in initiating primary branches by sprouting lateral buds of rapeseed plants.

Application of Zn had significant influence on number of primary branches per plant (Fig. 6 and Appendix V). The highest number of branches per plant (6.00) was obtained from Zn_2, 2 kg Zn/ha and the lowest number of branches per plant (5.08) was obtained from the control, Zn_0 and indicating that Zn increased number of primary branches per plant^{-1} as dose dependent manner.

Interaction effect between N and Zn was found significant on the number of primary branches per plant (Table 3 and Appendix V). The maximum number of branches per plant (7.00) was found in N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha whereas the lowest number of branches per plant (3.67) was found in N_0Zn_0, control treatment, that are correlate with Murtaza and Paul (1989) findings, they observed significant effect of nitrogen on the number of primary branches plant^{-1}. Alltogether, the result of this study suggests that N and Zn show synergistic effect on primary branches per plant of rapeseed plants.

Table 2. Combined effect of nitrogen and zinc on the number of leaves plant^{-1} of rapeseed at different days after sowing (DAS)

Treatments	Number of leaves plant^{-1}				
	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0Zn_0	5.00 b	7.00 b	8.33 e	16.7 d	18.7 c
N_0Zn_1	5.33 ab	7.33 ab	8.67 de	18.7 d	19.0 bc
N_0Zn_2	5.33 ab	8.00 ab	10.0 cde	19.3 d	20.0 bc
N_1Zn_0	5.00 b	7.67 ab	14.0 ab	25.7 bc	28.3 ab
N_1Zn_1	5.00 b	8.00 ab	11.7 bcde	27.7 bc	28.0 abc
N_1Zn_2	5.67 a	8.33 ab	11.7 bcde	26.0 bc	26.7 abc
N_2Zn_0	5.67 a	7.67 ab	11.0 bcde	26.7 bc	28.3 ab
N_2Zn_1	5.67 a	8.67 ab	11.3 bcde	29.3 ab	29.7 a
N_2Zn_2	5.67 a	9.33 a	16.0 a	32.3 a	32.7 a
N_3Zn_0	5.33 ab	8.33 ab	13.3 abc	25.3 c	27.7 abc
N_3Zn_1	5.33 ab	8.00 ab	11.3 bcde	28.0 bc	26.3 abc
N_3Zn_2	5.67 a	8.33 ab	12.0 bcd	28.7 bc	30.0 a
$LSD_{(0.05)}$	0.45	1.76	3.15	3.35	8.24
Significant level	*	*	*	*	*
CV (%)	7.69	12.9	16.0	14.7	18.5

In a column treatments having similar letter(s) do not differ significantly as per LSD

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

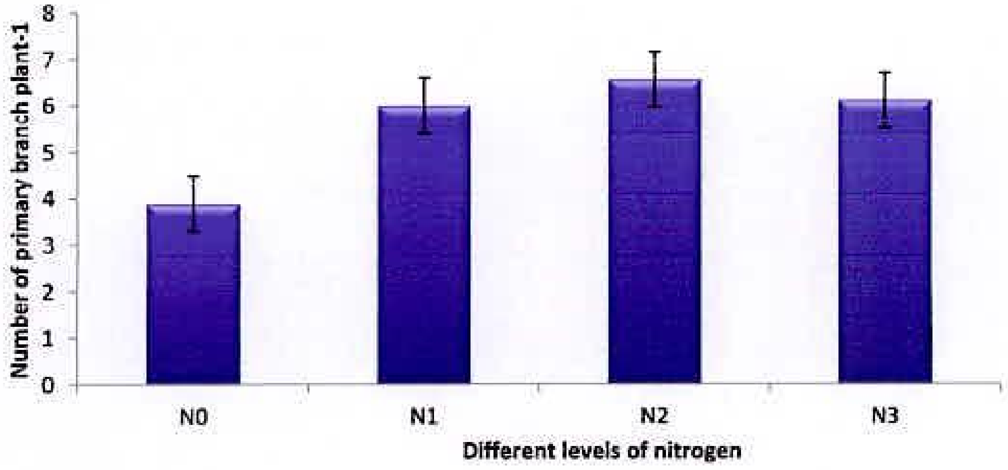

Fig. 5: Effect of nitrogen on the number of primary branches plant^{-1} of rapeseed (N_0 = without nitrogen, N_1 = 60 kg N /ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha, Error bars represent standard error).

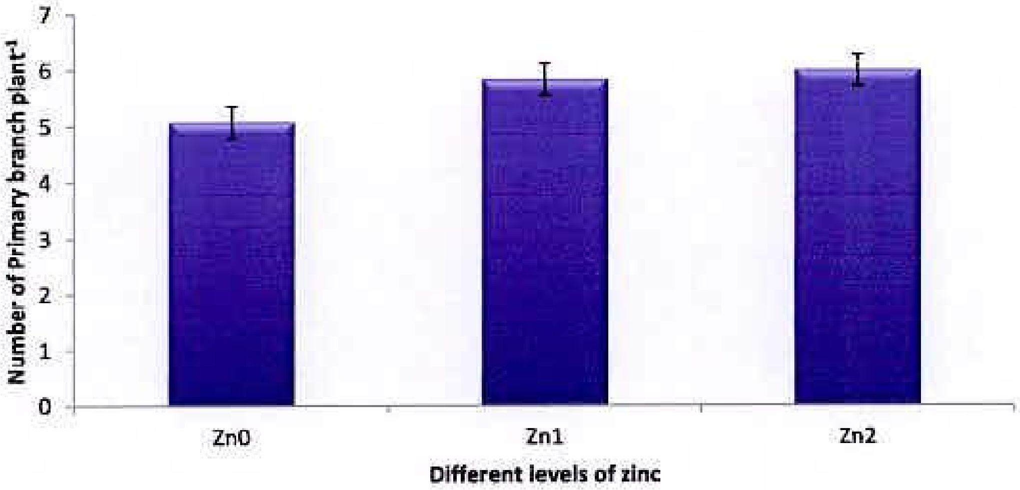

Fig. 6: Effect of different levels of zinc on the number of primary branches plant^{-1} of represent (Zn_0= no zinc, Zn_1 = 1 kg Zn/ha, Zn_2 =2kg Zn/ha, Error bars represent standard error).

Table 3. Combined effect of nitrogen and zinc on the number of primary branches plant^{-1} of rapeseed

Treatments	Number of Primary branches plant^{-1}
N_0Zn_0	3.67 d
N_0Zn_1	3.67 d
N_0Zn_2	4.33 cd
N_1Zn_0	5.67 abc
N_1Zn_1	6.33 ab
N_1Zn_2	6.00 abc
N_2Zn_0	6.00 abc
N_2Zn_1	6.67 ab
N_2Zn_2	7.00 a
N_3Zn_0	5.00 bcd
N_3Zn_1	6.33 ab
N_3Zn_2	7.00 a
$LSD_{(0.05)}$	1.66
Significant level	*
CV (%)	7.30

In column, means containing same letter indicate significantly similar under LSD at 5% level of significance. Values are the means of three replications

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0= no zinc, Zn_1 = 1 kg Zn/ha, Zn_2 =2kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

4.4 Length of inflorescence

Nitrogen is extremely important for the production of proteins in plants which promotes good foliage and healthy appearance but too much nitrogen will grow unhealthy plants thus induce less reproductive development and economic values. The N showed significant variation in the length of inflorescence (Fig. 7 and Appendix VI). The longest length of inflorescence (20.7, 31.2, 33.8 and 37.3 cm at 50, 60, 70 and 80 DAS, respectively) was produced by N_2, 120 kg N/ha but not to N_3 or 180 kg N/ha whereas N_0 produced the shortest length of inflorescence (26.9, 28.9, 29.8 and 30.9 cm at 50, 60, 70 and 80 DAS, respectively). This result suggests that the excess doses of N fail to increase the length of floral axis of rapeseed.

There was no significant difference among the Zn treatments in the length of inflorescence (Fig. 8. and Appendix VI). As evident from fig 8, the maximum length of inflorescence (19.7, 29.8, 33.3 and 36.2 cm at 50, 60, 70 and 80 DAS, respectively) was produced from 2 kg Zn/ha. The minimum length of inflorescence (18.3, 28.9, 31.6 and 33.1 cm at 50, 60, 70 and 80 DAS, respectively) was produced in control.

The analysis of variance (Table 4 and Appendix VI) indicated a significant variation among the treatment combinations in length of inflorescence. The maximum length of inflorescence (23.2, 31.9, 36.7 and 39.6 cm at 50, 60, 70 and 80 DAS, respectively) was found in N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha whereas the minimum length of inflorescence (12.7, 23.1, 28.1 and 27.0 cm at 50, 60, 70 and 80 DAS, respectively) was found in control (Table 4). Proper combination of N and Zn is necessary for optimal growth and development in higher plants.

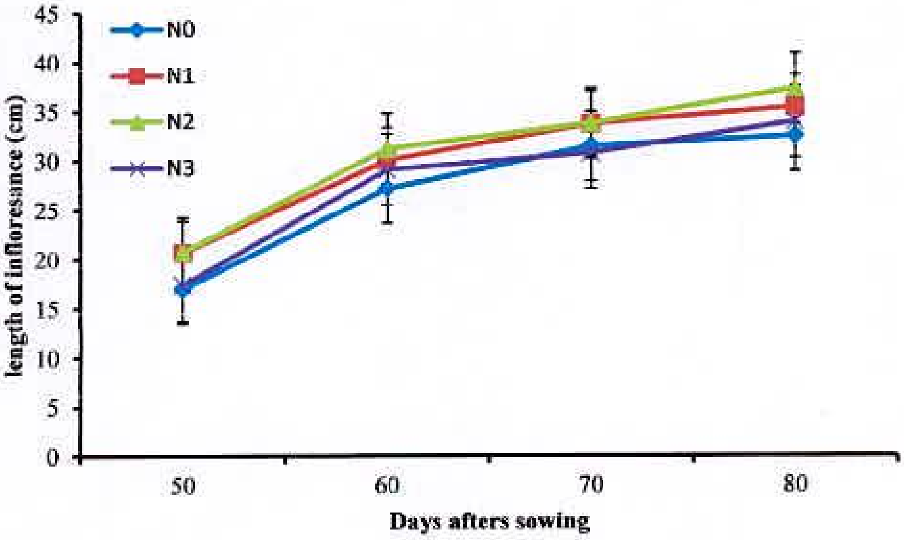

Fig. 7: Effect of nitrogen at different DAS on length of inflorescence plant^{-1} of rapeseed (DAS = Days after sowing, N_0 = without nitrogen, N_1 = 60 kg N /ha, N_2 = 120 kg N/ha, N_3 = 180 kg N/ha, Error bars represent standard error).

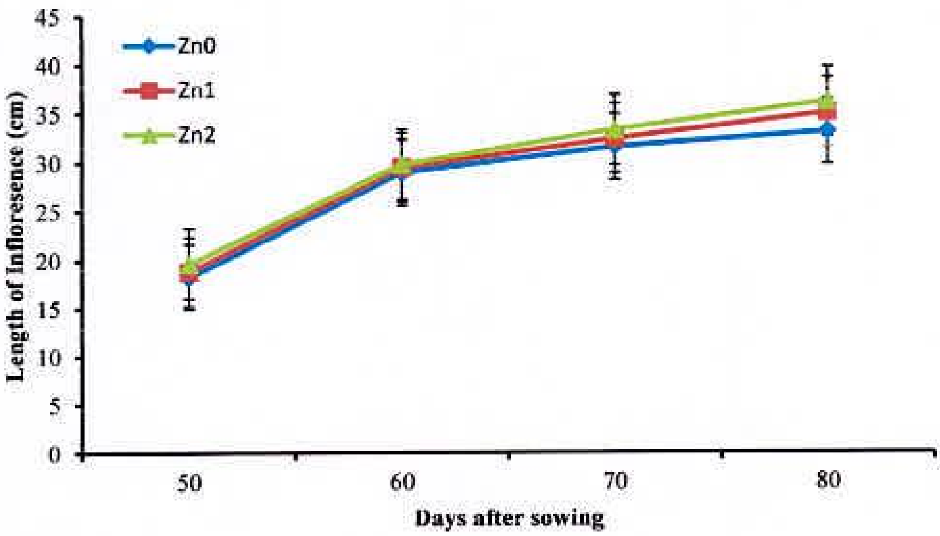

Fig. 8: Effect of different levels of zinc at different DAS on the length of inflorescence plant^{-1} of rapeseed (DAS = Days after sowing, Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 =2kg Zn/ha, Error bars represent standard error).

Table 4. Interaction effect of nitrogen and zinc on length of inflorescence of rapeseed at different days after sowing (DAS)

Treatments	Length of inflorescence (cm)			
	50 DAS	60 DAS	70 DAS	80 DAS
N_0Zn_0	12.7 c	23.1 c	28.1 c	27.0 d
N_0Zn_1	17.1 bc	31.6 a	32.5 abc	36.6 abc
N_0Zn_2	18.6 ab	28.6 ab	29.1 bc	32.7 bc
N_1Zn_0	21.3 ab	30.0 ab	34.3 abc	38.2 ab
N_1Zn_1	19.8 ab	30.8 a	33.8 abc	37.0 abc
N_1Zn_2	20.8 ab	31.0 a	33.3 abc	36.8 abc
N_2Zn_0	20.2 ab	30.0 ab	34.0 abc	34.5 abc
N_2Zn_1	18.7 ab	30.3 ab	34.7 ab	32.5 bc
N_2Zn_2	23.2 a	31.9 a	36.7 a	39.6 a
N_3Zn_0	20.7 ab	30.2 ab	32.8 abc	36.0 abc
N_3Zn_1	17.5 bc	27.1 b	28.5 bc	31.9 cd
N_3Zn_2	16.4 bc	28.2 ab	31.4 abc	34.8 abc
$LSD_{(0.05)}$	4.71	3.24	5.65	5.07
Significant level	*	*	*	*
CV (%)	22.25	12.57	10.29	20.11

In column, means containing same letter indicate significantly similar under LSD at 5% level of significance. Values are the means of three replications

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0 = without Zinc, Zn_1 = 1kg Zn/ha, Zn_2 =2kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

4.5 Number of siliquae plant^{-1}

The number of siliquae per plant of rapeseed/ mustard was highly affected nitrogen rates and their interaction.The N showed significant variation in the number of siliquae per plant (Table 5 and Appendix VII). The Maximum number siliquae per plant (38.3) was obtained in plots which received 120 kg N ha^{-1}. The minimum number of siliquae per plant (32.6) produced in control plots (no nitrogen application). Similar result also obtained by Shukla *et al.* (2002) and Singh *et al.* (2003) in rapeseed. These are consistent with the length of inflorescence of rapeseed.

There was a significant difference among the Zn in the number of siliquae per plant (Table 6 and Appendix VII). The maximum number of siliquae per plant (38.4) was produced in Zn_2 or with 2 kg Zn/ha and the minimum number of siliquae per plant (33.5) was produced in Zn_0 or control condition.

The analysis of variance (Table 7 and Appendix VII, Plate 3 and 4) indicated a significant variation among the treatment combinations of N and Zn in number of siliquae per plant. The maximum number of siliquae per plant (42.0) was found in N_2Zn_2, whereas the minimum number of siliquae per plant (26.80) was found in N_0Zn_0 treatment combination. These results are consistent with the results of length of inflorescence up to 80 DAS (Table 4).

Plate 3. Photograph shows the number of silliquae per plant with N_2Zn_2 treatment combination (120 kg N/ha and 2 kg Zn/ha).

Plate 4. Photograph shows the number of silliquae per plant with N_0Zn_0 treatment combination (without N and Zn).

4.6 Seed weight of hundred siliquae

Seed weight of hundred siliquae showed significant difference due to variation of doses of nitrogen (Table 5). The highest seed weight of hundred siliquae (0.76 g) was obtained from N_2 treatment. The lowest seed weight of hundred siliquae (0.55 g) was recorded in control treatment. These results are in agreement with the findings of Deekshitula *et al.* (1997) in Indian mustard, Bhagwan *et al.* (1996) and Patil *et al.* (1997) in mustard. They reported that seed weight of hundred siliquae in mustard increased with the application of nitrogen.

The Zn showed insignificant variation in the seed weight of hundred siliquae (Table 6 and Appendix VII). The highest seed weight of hundred siliquae (0.69 g) was obtained from Zn_2 treatment. The lowest seed weight of hundred siliquae (0.65 g) was obtained from control treatment.

The interaction effect of N and Zn was significant on seed weight of hundred siliquae (Table 7). The highest seed weight of hundred siliquae (0.83 g) was produced in N_2Zn_2. The lowest (0.52 g) was recorded in the treatment combination of N_0Zn_0.

4.7 Thousand seed weight

The application of nitrogen influenced significantly on the thousand seed weight (Table 5 and Appendix VII). The maximum thousand seed weight (7.63 g) was produced by N_2, which was statistically similar with N_1 and N_3 treatment and N_0 produced the lowest thousand seed weight (5.53 g). Ozer (2003), Singh, P.C. (2002) and Shamsuddin et al. (1987) also obtained highest 1000 seed weight with 120 kg N/ha.

The weight of thousand seed was significantly influenced by Zn (Table 6 and Appendix VII). The highest thousand seed weight (6.91 g) was obtained from Zn_2 treatment. The lowest thousand seed weight (6.52 g) was obtained from without Zn.

Thousand seed weight was significantly affected by both N and Zn (Table 7 and Appendix VII). The highest thousand seed weight (8.29 g) was found in N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha whereas the lowest thousand seed weight (5.21 g) was found in N_0Zn_0 treatment (Table 7). These results suggest that combined use of appropriate doses of N and Zn produced maximum thousand seed weight than the use of same dose of N or Z along.

4.8 Seed yield $plot^{-1}$

The N showed significant variation in the seed weight per plot (Table 5 and Appendix VII). The maximum seed yield per plot (1.61 kg) was produced by N_2 whereas N_0 produced the minimum seed yield per plot (3.14 g). Seed weight increased with the increasing rates of N fertilizer up to 120 kg/ha and then declined. These obtained results are similar with the finding of seed weight of 100 siliquae (Table 5). The higher seed yield per plot was also obtained with same N rate as reported by Singh *et al.* (1998), Tuteja *et al.* (1996).

There was a significant difference among the Zn fertilizer in the seed yield per plot (Table 6 and Appendix VII). The maximum seed yield per plot (1.49 kg) was produced in Zn_2 treatment. The minimum seed yield per plot (0.84 kg) was produced in without Zn condition.

Seed yield per plot indicated a significant variation among the treatment combinations of N and Zn (Table 7 and Appendix VII). The maximum seed yield per plot (1.90 kg) was found in N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn /ha, whereas the minimum seed yield per plot (0.17 kg) was found in N_0Zn_0 treatment.

4.9 Seed yield

The seed yield of rapeseed per plot was converted into per hectare, and has been expressed in metric tons (Table 5 and Appendix VII). The different dose of N had significant effect on the yield of seed per hectare. The maximum yield of seed per hectare (3.57 t) was obtained from N_2, 120 kg N/ha, whereas the minimum yield of seed per hectare (1.50 t) was obtained from N_0, without N. Further increase in N level beyond 120 kg/ha could not improve the seed yield. These results is consistent with the N-induced increase of growth parameters (Fig. 1, 3, 5, 7) along with number of siliquae/plant, seed weight of 100 siliquae, seed weight /plant and thousand seed weight (Table 5). The higher seed yield/ha was also obtained with same N rate reported by Singh and Prasad (2003), Singh *et al.* (2003), Shukla *et al.* (2002). Therefore, N can enhance the seed yield (t/ha) of rapeseed variety BARI sarisha 15.

The total yield of rapeseed varied significantly due to the application of different levels of Zn fertilizer (Table 6 and Appendix VII). The highest yield of seed (3.31 t/ha) was obtained from Zn_2, 2 kg Zn/ha while Zn_0 gave the lowest (1.04 t/ha) yield. This result showed that the yield of mustard increased gradually with the higher doses of Zn fertilizer. Interestingly, this result is consistent with the Zn-induced yield components such as number of siliquae /plant, thousand seed weight and seed yield (Table 6) rather than growth parameters (Fig. 2, 4, 6, 8). Therefore, higher dose of Zn can increase seed yield of rapeseed.

The combined effect of N and Zn fertilizer was significant on yield of seed per hectare (Table 7 and Appendix VII). The highest yield of seed per hectare (4.22 tones) was obtained from N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha. The lowest yield of seed per hectare (0.37 tones) was obtained from N_0Zn_0 treatment. These results are consistent with the results of plant height, number of leaves and primary branch and length of inflorescence, number of siliquae per plant (Table 1, 2, 3 and 4; Plate 1, 2,3 and 4). Nitrogen (N) increases crop yield by influencing different growth parameters and by producing more vigorous growth and development as reflected via increasing plant height, number of flowering branches, total plant weight, leaf area index and number and weight of siliquae and seeds per plant (Alien and Morgan, 1972). Therefore, these results suggest that the combined use of 120 kg N/ha and 2 kg Zn/ha produce the highest seed yield of rapeseed under the climatic and edaphic condition at Sher-e-Bangla Agricultural University, Dhaka.

Table 5. The main effect of nitrogen on yield contributing characters and seed yield of rapeseed

Treatments	No. of siliquae/plant	Seed weight of 100 siliquae (g)	1000 seed weight (g)	Seed yield per plot (kg)	Seed yield (t/ha)	Harvest index (%)
N_0	32.6 b	0.55 b	5.53 b	0.68 d	1.50 d	48.1 c
N_1	36.9 a	0.68 ab	6.84 ab	1.18 b	2.61 b	50.1 bc
N_2	38.3 a	0.76 a	7.63 a	1.61 a	3.57 a	54.6 a
N_3	38.1 a	0.69 ab	6.85 ab	1.12 c	2.50 c	52.0 b
$LSD_{(0.05)}$	3.74	0.16	1.88	0.03	0.08	2.6
Significant level	*	*	*	*	*	*
CV (%)	**12.9**	**10.6**	**8.11**	**6.22**	**7.23**	**8.15**

Table 6. Effect of zinc on yield contributing characters and seed yield of rapeseed

Treatments	No. of siliquae/plant	Seed weight of 100 siliquae(g)	1000 seed weight (g)	Seed yield per plot (kg)	Seed yield (t/ha)	Harvest index (%)
Zn_0	33.5 b	0.65 a	6.52 a	0.84 c	1.88 c	50.0 c
Zn_1	37.6 a	0.67 a	6.71 a	1.10 b	2.45 b	51.3 b
Zn_2	38.4 a	0.69 a	6.91 a	1.49 a	3.31 a	52.4 a
$LSD_{(0.05)}$	3.63	0.54	2.54	0.04	0.11	0.7
Significant level	*	**NS**	**NS**	*	*	*
CV (%)	**12.9**	**10.6**	**8.11**	**6.22**	**7.23**	**8.15**

In a column treatments having similar letter(s) do not differ significantly as per LSD

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

NS= Non significant

Table 7. Interaction effect of nitrogen and zinc on yield contributing characters and seed yield of rapeseed.

Treatments	No. of siliquae/plant	Seed weight of 100 siliquae (g)	1000 seed weight (g)	Seed yield per plot (kg)	Seed yield (t/ha)	Harvest index (%)
N_0Zn_0	26.8 g	0.52 b	5.21 b	0.17 j	0.37 j	45.7 d
N_0Zn_1	36.0 cdef	0.55 ab	5.54 ab	0.55 i	1.22 i	48.9 cd
N_0Zn_2	34.9 ef	0.58 ab	5.85 ab	1.69 c	3.76 c	49.8 c
N_1Zn_0	34.1 f	0.64 ab	6.41 ab	0.18 j	0.41 j	50.7 bc
N_1Zn_1	38.6 bc	0.69 ab	6.87 ab	1.34 e	2.98 e	50.0 bc
N_1Zn_2	38.1 bcd	0.72 ab	7.23 ab	1.79 b	3.98 b	49.7 c
N_2Zn_0	36.9 cde	0.73 ab	7.27 ab	0.82 g	1.82 g	52.7 bc
N_2Zn_1	35.5 def	0.73 ab	7.34 ab	1.80 b	3.99 b	54.2 ab
N_2Zn_2	42.0 a	0.83 a	8.29 a	1.90 a	4.22 a	56.9 a
N_3Zn_0	36.4 cdef	0.66 ab	6.55 ab	0.66 h	1.47 h	50.9 bc
N_3Zn_1	40.1 ab	0.71 ab	7.09 ab	1.30 f	2.89 f	51.9 bc
N_3Zn_2	38.4 bc	0.69 ab	6.91 ab	1.55 d	3.44 d	53.0 abc
$LSD_{(0.05)}$	2.43	0.26	2.38	0.02	0.05	3.8
Significant level	*	*	*	*	*	*
CV (%)	8.85	10.6	14.3	20. 1	15.7	8.16

In a column treatments having similar letter(s) do not differ significantly as per LSD

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

4.10 Harvest index

Harvest index indicates the partitioning of dry matter between reproductive and vegetative part. The ratio of economic yield to biological yield is termed as harvest index. Higher HI might be beneficial in obtaining higher economic yield. A significant increase in HI of was found in rapeseed due to different nitrogen. The highest HI of 54.6% was observed in treatment N_2 (120 kg N/ha) and the lowest (48.1%) from N_0 (control treatment, Table 5).

There was significant variation in harvest index due to the zinc. The maximum HI (52.4%) was obtained from Zn_2 treatment and the minimum (50.0%) was obtained in control treatment (Table 6).

Combined effect of N and Zn had a significant variation on HI. The highest HI (56.9%) was obtained from N_2Zn_2 treatment while the lowest (45.7%) from N_0Zn_0 (Table 7).

4.11 Oil content

Oil content show significant influence by different N levels (Fig. 9 and Appendix VII). Fig. 9 revealed that application of N at 120 kg/ha (N_2) gave the maximum oil content (43.09 %), which was statistically similar with N_3 (180 kg N/ha) treatment and the minimum oil content (41.60%) was obtained from N_0 levels. Singh *et al.* (2004) also reported that N application did not affect the oil content of rapeseed. The present results of oil content of rapeseed suggest that N improve the oil percent up to 120 kg N /ha but not 180 kg /ha.

The oil content varied significantly due to the application of different levels of zinc fertilizer (Fig. 10 and Appendix VII). The highest oil content (42.81 %) was obtained from Zn_2, 2 kg Zn/ha, which was statistically similar with Zn_1 (1 kg Zn/ha) while Zn_0 gave the lowest (42.13 %) oil content. These results suggest that Zn can synthesis oil in rapeseed and higher levels of Zn improve the percent of oil in rapeseed.

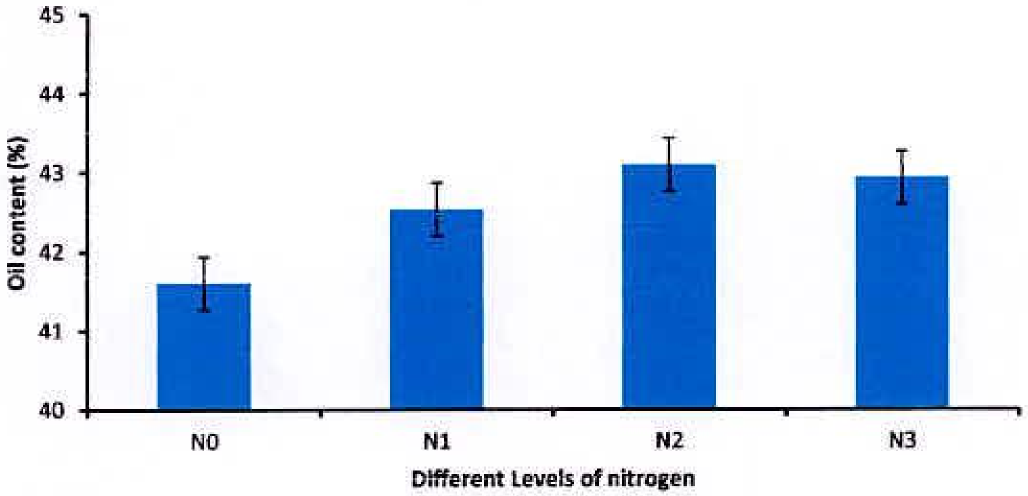

Fig. 9. The effect of nitrogen on oil content of rapeseed (N_0 = without nitrogen, N_1 = 60 kg N /ha, N_2 = 120 kg N/ha, N_3 = 180 kg N/ha, Error bars represent standard error).

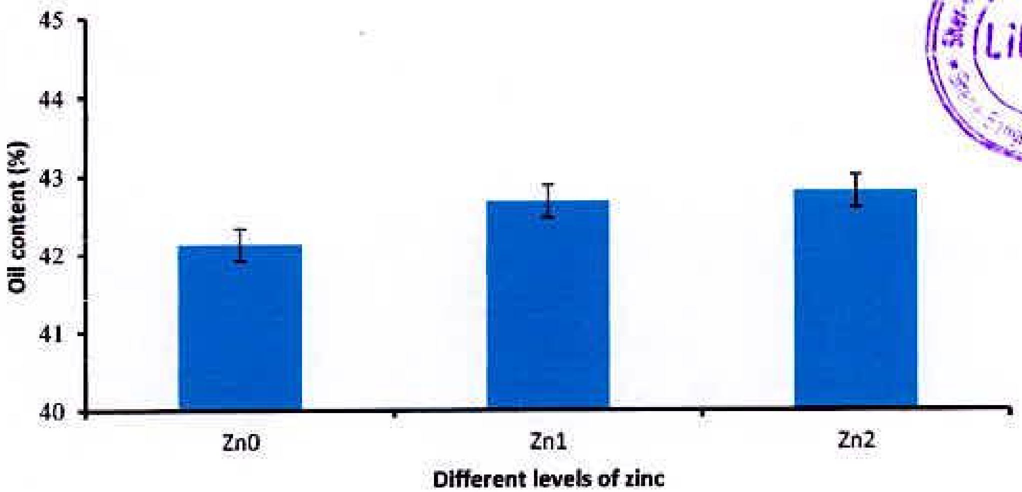

Fig. 10. The effect of zinc on oil content of rapeseed (Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn /ha, Error bars represent standard error).

The combined effect of N and Zn fertilizer was significant on oil content of rapeseed (Table 8 and Appendix VII). The highest oil content (43.29 %) was obtained from N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha whereas the lowest oil content (40.11 %) was obtained from N_0Zn_0 treatment combination, 0 kg N/ha and 0kg Zn /ha (Table 8). Present result of oil content of rapeseed indicate that the combined use of N and Zn can enhance the percent of rapeseed oil content as compared to N and Zn alone Therefore, it can be suggested that the 120 kg N/ha along with 2 kg Zn/ha is the best combination for containing higher amount of oil percent in rapeseed.

4.12 Germination percentage

The germination percentage of seed was not significantly affected of this rapeseed variety (Fig. 11 and Appendix VII). The maximum germination percentage of seed (97.89 %) was obtained from N_3 (170 kg N/ha) whereas the minimum germination percentage of seed (93.44 %) was obtained with N_2 (120 kg N/ha). Similarly, germination percentage of seed was not influenced by Zn (Fig. 12 and Appendix VII). The maximum germination percentage of seed (96.00 %) was obtained from Zn_1 (1 kg Zn/ha) and the minimum (94.75 %) from Zn_0 (control). Again, interaction effect of N and Zn also had significant variation on germination percentage of seed (Table 8 and Appendix VII). The maximum germination percentage of seed (99.00 %) was obtained from N_3Zn_0, while the shortest (92.00 %) was obtained from N_2Zn_1 (Table 8).

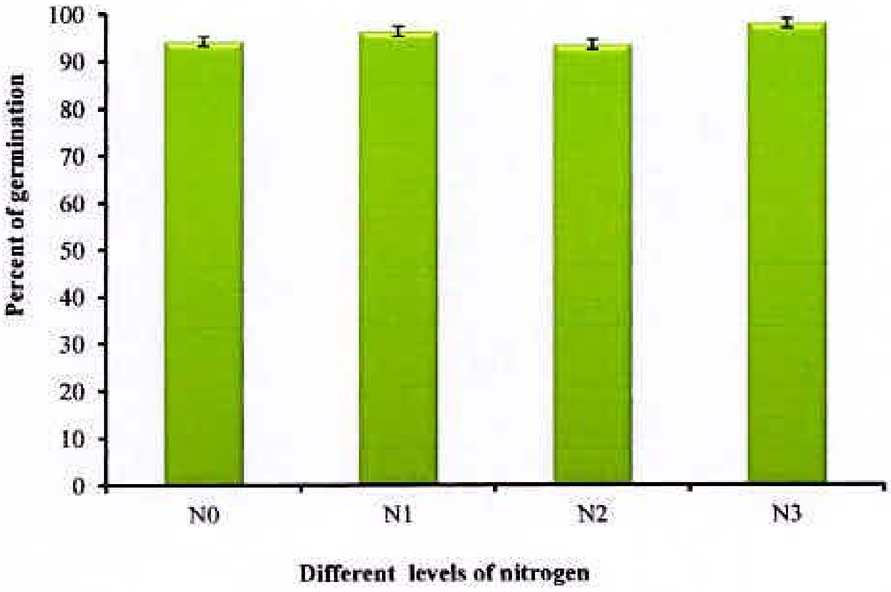

Fig. 10. The effect of nitrogen on germination percentage of rapeseed (N_0 = without nitrogen, N_1 = 60 kg N /ha, N_2 = 120 kg N/ha, N_3 = 180 kg N/ha, Error bars represent standard error).

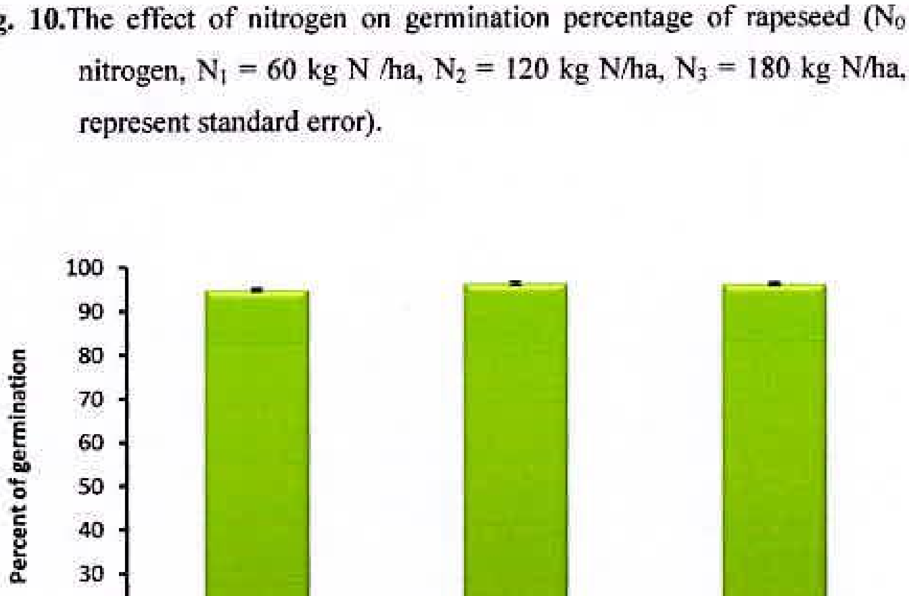

Fig. 11. The effect of zinc on germination percentage of rapeseed (Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn /ha, Error bars represent standard error).

Table 8. Interaction effect of nitrogen and zinc on oil content and germination of rapeseed

Treatments	Oil content (%)	Percent of germination
N_0Zn_0	40.1 d	93.00
N_0Zn_1	41.8 c	96.00
N_0Zn_2	42.9 ab	93.67
N_1Zn_0	42.3 bc	94.00
N_1Zn_1	43.1 ab	97.00
N_1Zn_2	42.2 bc	98.00
N_2Zn_0	43.2 ab	93.00
N_2Zn_1	42.9 ab	92.00
N_2Zn_2	43.3 a	95.33
N_3Zn_0	43.0 ab	99.00
N_3Zn_1	43.0 ab	99.00
N_3Zn_2	42.8 ab	95.67
$LSD_{(0.05)}$	0.84	1.08
Significant level	*	NS
CV (%)	5.16	6.35

In a column treatments having similar letter(s) do not differ significantly as per LSD

N_0 = without nitrogen, N_1 = 60 kg N/ha , N_2 = 120 kg N/ha , N_3 = 180 kg N/ha

Zn_0 = without zinc, Zn_1 = 1 kg Zn/ha, Zn_2 = 2 kg Zn/ha

CV = Co-efficient of Variation

LSD = Least Significant Difference

* = Significant at 5 % level

NS=Non significant

Chapter V

SUMMARY AND CONCLUSIONS

The experiment was undertaken during rabi season, November 2011 to February 2012 to examine the response to different levels of nitrogen and zinc on yield and seed quality of rapeseed variety BARI Sarisha 15. In this experiment, the treatment consisted of four different N levels viz. N_0 = 0 kg N/ha, N_1 = 60 kg N/ha, N_2 = 120 kg N/ha and N_3= 180 kg N/ha, and three different level of Zn viz. Zn_0 = 0 kg/ha, Zn_1= 1 kg Zn/ha, Zn_2 =2 kg Zn/ha. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The amount of fertilizers in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid as a source of N, P, K, S, Zn and B respectively were applied according to treatment and area of experimental unit plot. The collected data were statistically analyzed for evaluation of the treatment effect. Results showed that a significant variation among the treatments in respect majority of the observed parameters.

There is significant difference among the different levels of N in respect of almost all parameters. The tallest plant height (28.9, 34.9, 81.2, 94.0 and 95.8 cm at 20, 30, 40, 50 and 60 DAS respectively) was recorded with N_2, 120 kg N ha^{-1}. The maximum number of leaves per plant (5.59, 8.56, 12.9, 29.7 and 30.2 at 20, 30, 40, 50 and 60 DAS, respectively) was produced by 120 kg N/ha. The maximum number of branches per plant (6.56) was produced by 120 kg N/ha. The longest length of inflorescence (20.7, 31.2, 33.8 and 37.3 cm at 50, 60, 70 and 80 DAS, respectively) was produced by N_2, 120 kg N/ha. The maximum number siliquae per plant (38.3) was obtained in plots which received 120 kg N ha^{-1}. The highest seed weight of hundred siliquae (0.76 g) was obtained from N_2 treatment. The maximum thousand seed weight (7.63 g) was produced by N_2. The maximum seed yield per plot (1.61 kg) was produced by N_2. The maximum yield of seed per hectare (3.57 t) was obtained from N_2, 120 kg N/ha, whereas the minimum yield of seed per hectare (1.50 t) was obtained from N_0, without N. The highest HI of 54.62% was observed in treatment N_2 (120 kg N/ha). The maximum germination percentage of seed (97.89 %) was obtained from N_3 (180 kg N/ha). The application of N at 120 kg/ha (N_2) gave the maximum oil content (43.09 %).

Plant height, number of leaves and length of inflorescence did not show any statistical difference in response of application of Zn. The tallest plant height (27.3, 34.1, 79.4, 91.4 and 83.6 cm at 20, 30, 40, 50 and 60 DAS, respectively) was produced with Zn_2, 2 kg Zn/ha. The maximum number of leaves per plant (5.50, 8.25, 24.8 and 26.6 cm at 20, 30, 40, and 50 DAS, respectively), number of branches per plant (6.00), length of inflorescence (19.7, 29.8, 33.3 and 36.2 cm at 50, 60, 70 and 80 DAS, respectively) was produced with Zn_2, 2 kg Zn/ha. The maximum number of siliquae per plant (38.4), seed weight of hundred siliquae (0.69 g) and thousand seed weight (6.91 g) was produced in Zn_2, 2 kg Zn/ha. The maximum seed yield per plot (1.49 kg) was produced in Zn_2 treatment. The highest yield of seed (3.31 t/ha) was obtained from Zn_2, 2 kg Zn/ha while Zn_0 gave the lowest (1.04 t/ha) yield. The maximum HI (52.4%) was obtained from Zn_2 treatment. The maximum germination percentage of seed (96.00 %) was obtained from Zn_1 (1 kg Zn/ha). The highest oil content (42.81 %) was obtained from Zn_2, 2 kg Zn/ha.

The combinations of N and Zn had significant effect on almost all parameter. The tallest plant height (30.1, 37.3, 84.3, 96.1, and 98.5 cm at 20, 30, 40, 50 and 60 DAS, respectively) was found in N_2Zn_2 treatment combination. The maximum number of leaves per plant (5.67, 9.33, 16.0, 32.3 and 32.7 at 20, 30, 40, 50 and 60 DAS, respectively), number of branches per plant (7.00) and length of inflorescence (23.2, 31.9, 36.7 and 39.6 cm at 50, 60, 70 and 80 DAS, respectively) was found in N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha. The maximum number of siliquae per plant (42.0), seed weight of hundred siliquae (0.83 g), thousand seed weight (8.29 g) was found in N_2Zn_2, 120 kg N/ha with 2 kg Zn/ha. The maximum seed yield per plot (1.90 kg) was found in N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn /ha. The highest yield of seed per hectare (4.22 tones) was obtained from N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha. The lowest yield of seed per hectare (0.37 tones) was obtained from N_0Zn_0 treatment. The highest HI (56.9%) was obtained from N_2Zn_2 treatment. The maximum germination percentage of seed (99.00 %) was obtained from N_3Zn_0. The highest oil content (43.29 %) was obtained from N_2Zn_2 treatment combination, 120 kg N/ha and 2 kg Zn/ha.

Considering the above results, it may be summarized that morphological parameters, seed yield and oil content contributing parameters of rapeseed are positively correlated with N and Zn application. Therefore, the present experimental results suggest that the combined use of 120 kg N/ha and 2 kg Zn/ha along with recommended doses of other fertilizer would be beneficial to increase the seed yield and oil content of rapeseed variety BARI sarisha 15 under the climatic and edaphic condition of Sher-e-Bangla Agricultural University, Dhaka.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for analogy the accuracy of the experiment.
2. It needs to conduct more experiments with N and micronutrient Zn whether can regulate the morphological characters, yield and seed quality of rapeseed BARI sarisha 15.
3. It needs to conduct related experiment with other varieties mustard and rapeseed.
4. Scope to conduct advance experiments how N and Zn physiologically increase seed yield and improve seed quality of rapeseed.

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APPENDICES

Appendix I: Physical and chemical characteristics of initial soil (0-15 cm depth)

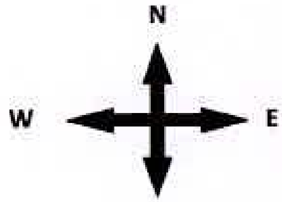
A. Physical composition of soil

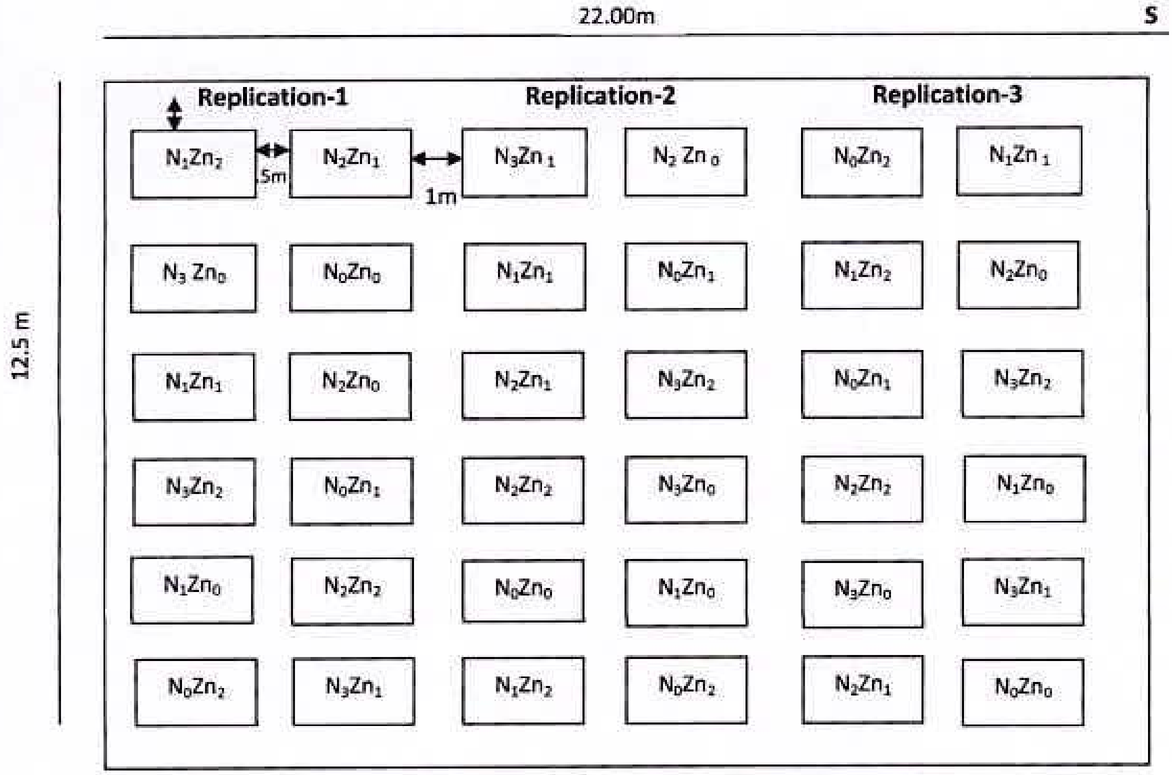
Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-do-
Clay	36.66	-do-
Texure class	Clay loam	-do-

B. Chemical composition of soil

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

Appendix II. Layout of the experimental plot





Unit plot size:

3 m x 1.5 m

N = Nitrogen

Zn= Zinc

Factor A: Nitrogen

N_0= without nitrogen
N_1=60 kg N/ha
N_2=120 kg N/ha
N_3=180 kg N/ha

Factor B: Zinc

Zn_0= without zinc

Zn_1=1 kg Zn/ha

Zn_2=2 kg Zn/ha

Appendix III: Analysis of variance of the data on plant height of rapeseed as influenced by different levels of nitrogen and zinc

Sources of Variation	Degrees of freedom	Mean Square				
		Plant Height				
		20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	1267.64	103.16	255.96	134.95	182.94
Factor A (nitrogen)	3	50.14*	122.91*	166.30*	162.56*	182.17*
Factor B (zinc)	2	1.68^{NS}	40.35^{NS}	111.76^{NS}	13.95^{NS}	12.54^{NS}
A×B	6	1.47*	8.48*	34.75*	12.20*	50.40*
Error	22	0.86	18.32	48.17	44.66	42.30

*significant at 5% level of probability,
NS- Non significant

Appendix IV: Analysis of variance of the data on number of leaves per plant of rapeseed as influenced by different levels of nitrogen and zinc

Sources of Variation	Degrees of freedom	Mean Square				
		No. of Leaves per plant				
		20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	2.111	35.194	84.194	138.528	55.83
Factor A (nitrogen)	3	0.111*	27.741*	221.213*	210.704*	36.481*
Factor B (zinc)	2	0.111^{NS}	8.361^{NS}	3.528^{NS}	1.861^{NS}	5.803^{NS}
A×B	6	0.333*	8.657*	11.491*	9.009*	21.43*
Error	22	0.172	3.467	13.922	23.649	17.721

*significant at 5% level of probability,
NS- Non significant

Appendix V: Analysis of variance of the data on number of primary branches of mustard as influenced by different levels of nitrogen and zinc

Sources of Variation	Degrees of freedom	Mean Square No. of Primary branches
Replication	2	0.861
Factor A (nitrogen)	3	12.769*
Factor B (zinc)	2	2.861*
A×B	6	0.602*
Error	22	0.952

*significant at 5% level of probability,

Appendix VI: Analysis of variance of the data on length of inflorescence of rapeseed as influenced by different levels of nitrogen and zinc

Sources of Variation	Degrees of freedom	Mean Square			
		Length of inflorescence			
		50 DAS	60 DAS	70 DAS	80 DAS
Replication	2	55.83	48.677	28.901	33.741
Factor A (nitrogen)	3	36.481*	38.7*	40.161*	21.921*
Factor B (zinc)	2	5.803 NS	29.216 NS	34.421 NS	9.018 NS
A×B	6	21.43*	34.626*	42.56*	25.276*
Error	22	17.721	48.957	56.05	11.139

*significant at 5% level of probability,
NS- Non significant

Appendix VII: Analysis of variance of the data on yield contributing characters of rapeseed as influenced by different levels of nitrogen and zinc

Sources of Variation	Degrees of freedom	Mean Square							
		No. of siliquae/plant	Seed weight of 100 siliquae (g))	1000 seed weight (g	Seed weight/plot (g)	Seed yield (t/ha)	Harvest Index (%)	Oil content (%)	Germination (%)
Replication	2	3.73	0.01	1.13	0.00	0.01	33.81	0.14	13.86
Factor A (nitrogen)	3	64.46*	0.07*	6.82*	1.30*	6.43*	68.90*	4.05*	36.77NS
Factor B (zinc)	2	80.51*	0.00NS	0.45*	1.27*	6.27*	16.88*	1.57*	5.03NS
A×B	6	20.03*	0.01*	0.52*	1.18*	5.82*	5.04*	1.72*	11.77NS
Error	22	22.07	0.02	2.36	0.00	0.00	17.40	0.24	5.01

*significant at 5% level of probability,
NS- Non significant