INFLUENCE OF APPLICATION METHOD OF NITROGEN ON THE GROWTH AND YIELD OF MUSTARD

UMME JABIN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY,

DHAKA-1207

June, 2010

INFLUENCE OF APPLICATION METHOD OF NITROGEN ON THE GROWTH AND YIELD OF MUSTARD

By

UMME JABIN
REGISTRATION NO. 05-01572

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: January- June, 2010

Approved by:

……………………………..
(Dr. Md. Fazlul Karim)
Professor
Supervisor

…………………………….
(Dr. Md. Jafar Ullah)
Professor
Co-supervisor

…………………………………
(Prof. Dr. Md. Fazlul Karim)
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled, "**INFLUENCE OF APPLICATION METHOD OF NITROGEN ON THE GROWTH AND YIELD OF MUSTARD"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE (M.S.) IN AGRONOMY*, embodies the result of a piece of *bona fide* research work carried out by **UMME JABIN,** Registration No. **05-01572** 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.

Dr. Md. Fazlul Karim
Professor
Department of Agronomy
Sher-e-Bangla Agricultural University
Supervisor

Dated:

Place: Dhaka, Bangladesh

DEDICATED

TO

MY ADORED PARENTS

AND

HUSBAND

ACKNOWLEDGMENTS

All praises to almighty and kindful "Allah" to enable the author to pursue higher study and to complete the research work as well as to submit the thesis for the degree of Master of Science (M. S.) in Agronomy from Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

The author would like to express her keen gratefulness to the supervisor Prof. Dr. Md. Fazlul Karim, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for her regular supervision, continuous guidance, precious suggestions, beneficial criticisms, helpful advice, inspiration and encouragement during experimentation, data collection and in preparation of this thesis.

The author sincerely expresses her warm respect and boundless gratitude to Prof. Dr. Jafar Ullah, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice.

The author would like to express a very special thanks and her deepest respect to Mr. Sheikh Muhammad Masum, Lecturer, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207 for his valuable time to prepare this thesis.

The author wishes to express her cordial thanks to all departmental and field staff specially Jasim for their active help during the experimental period.

The author intends to express heartful gratitude and deepest appreciation to her beloved parents, elder sister, younger brother, husband and other relative's for their heartiest, ever ending prayer, encouragement, moral support and love with cordial understanding to reach author upto this land mark.

ABSTRACT

The field experiment was conducted at the agronomy field of Sher-e-Bangla agricultural university, Dhaka during the rabi season (November- February) 2009-2010 to study the influence of application method of nitrogen (N) on the growth and yield of mustard. The experiment was laid out in randomized complete block design (RCBD) with three replications. Two forms of nitrogen fertilizer i.e. prilled urea (PU) and urea super granule (USG) were used in this experiment with different application methods. The treatments were i.e. T_1= Prilled Urea (PU) broadcasted (conventional method), T_2= PU given in the side furrows, T_3= PU given between two rows, T_4=PU and seed given in the same furrows, T_5= Urea Super Granular (USG) placed at 5 cm depth as basal, T_6= USG placed at 5 cm depth at 10 days after sowing (DAS), T_7= USG placed at 5 cm depth at 20 DAS, T_8= USG placed at 5 cm depth at 30 DAS, T_9= USG placed at 10 cm depth as basal, T_{10}= USG placed at 10 cm depth at 10 DAS, T_{11}= USG placed at 10 cm depth at 20 DAS, T_{12}= USG placed at 10 cm depth at 30 DAS, T_{13}= USG placed at 15 cm depth as basal, T_{14}= USG placed at 15 cm depth at 10 DAS, T_{15}= USG placed at 15 cm depth at 20 DAS and T_{16}= USG placed at 15 cm depth at 30 DAS. Results showed that USG placed in 5 cm depth at 20 DAS gave the highest seed yield (3.59 t ha^{-1}) along with all the higher yield components i.e. siliquae $plant^{-1}$ (58.60), seeds $siliqua^{-1}$ (32.00), 1000 seed weight (3.56 g) which reflected in higher value of biological yield (6.78 t ha^{-1}) and harvest index (52.62%). On the other hand, PU (conventional method) gave seed yield (2.58 t ha^{-1}) attributed to lower value of yield components i.e. siliquae $plant^{-1}$ (44.15), seeds $siliqua^{-1}$ (31.66), 1000 seed weight (3.30 g) with minimum biological yield (6.65t ha^{-1}) and harvest index (37.03). In contrast, the highest stover yield (4.07 t ha^{-1}) was found in conventional (broadcasting) use of PU. The use of USG out yielded PU by 39.14% when this method required about 52.38% less urea than the amount of PU. Therefore, use of USG had two fold advantages over conventional use of PU.

CONTENTS

LIST OF TABLES

LIST OF FUGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BARI	=	Bangladesh Agricultural Research Institute
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centi-meter
cv.	=	Cultivar
DAS	=	Days after sowing
DAT	=	Days after transplanting
^{0} C	=	Degree Centigrade
DF	=	Degree of freedom
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
hr	=	hour
kg	=	kilogram
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
me	=	Milli-equivalent
MV	=	Modern variety
mm	=	Millimeter
viz.	=	namely
N	=	Nitrogen
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
PU	=	Prilled urea
SAU	=	Sher-e- Bangla Agricultural University
t ha^{-1}	=	Tons per hectare
USG	=	Urea super granules
Zn	=	Zinc
µg	=	Microgram

Chapter 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Mustard is an oil seed crop belongs to the genus *Brassica* of the family Cruciferae. It is the main cultivable edible oil seed crop of Bangladesh. Mustard covers the land area of 216800 hectares in Bangladesh and produces about 183500 metric tons of oilseeds (BBS, 2007). Bangladesh occupies the 5th place in respect of total oilseed production in the world and occupies the first position in respect of area and production among the oil crops grown in Bangladesh (BBS, 2010). Mustard is the most important popular oil crop which is grown in rabi season in Bangladesh. Only a few decades ago, in Bangladesh mustard oil was the exclusive cooking oil, medicinal ingredient and supplies fat in our daily diet.

Domestic production of edible oil almost entirely comes from rapeseed and mustard occupying only about 2% area of total cropped area in Bangladesh (BBS, 2002). The annual oil seed production of 0.41 million tons of which the share of rapeseed-mustard was 0.21 million tons, which comes about 52 % of the total edible oil seed production. Mustard covers about 61.2% of the total acreage under oil seed and 52.6% of the total oil seed production in Bangladesh (BBS, 2005). The yield of this crop in Bangladesh is much lower compared to other countries. The average yield of rapeseed-mustard in Bangladesh is very low (0.76 t ha^{-1}) that is less than 50% of the world average (FAO, 2004).

Bangladesh is deficit in edible oil, which cost valuable foreign currency for importing seeds and oil. Annually country is producing about 2.80 Lac m tons of edible oil as against the requirement of 9.80 Lac m tons thus import oil is regular phenomenon of this country (BBS, 2010). Every year Bangladesh imports 2085864 metric tons of edible oil to meet up the annual requirement of the country, which cost Tk. 64430 million (BBS, 2007). Both the acreage and production of the crop have been decreasing since 1990 mainly due to ingression of cereal crops like- rice, maize, wheat etc. Delayed harvest of transplanted aman rice and wetness of soil are another reason which hinders mustard cultivation in rabi season (BARI, 2008). Recently BARI has released some mustard varieties, which have high yield potential. But farmers are experienced with lower yield of mustard with their local varieties with poor crop management practices.

The yield of mustard can be augmented with the use of high yielding varieties along with appropriate agronomic management. Fertilizer is the depending source of nutrient that can be used to boost up growth and yield of rapeseed (Sinha *et al.*, 2003). High yielding varieties of mustard is very responsive to fertilizers especially nitrogen (Patel *et al.,* 2004). This element has tremendous influence on plant height, dry matter accumulation and all the yield attributes (Tripathi and Tripathi, 2003). Excessive use of this element may produce too much of vegetative growth and thus fruit production may be impaired (Sheppard and Bates, 1980). An efficient method and time of application is very much important for proper utilization of nitrogen by plants (Ibrahim *et al.*, 1989).

Urea is the principal source of N, which is the essential element in determining the yield potential (Mae, 1997). The predominant form of nitrogen fertilizer granules urea is used in

Bangladesh as prilled urea. Traditionally mustard is cultivated with prilled urea (PU) which can be lost in the field in various ways as- ammonia volatilization, denitrification, run off and leaching and thus plants suffer from proper nutrition (Dinnes *et al.,* 2002*)*. It is reported that about 40% of applied nitrogen as prilled urea in the oxidized zone of soil is used by the plant and rest enters to loss process (De Datta and Buresh, 1989; Cassman *et al.*, 2002). As prilled urea is dynamic and reactive in nature, it losses represent not only an economic drain for farmers but also have negative impact on the environment since the reactive compounds of nitrogen deteriorate water quality and contribute to global climate change (Gallowya *et al.*, 2003).

The newly introduced Urea Super Granules (USG), 'Guti Urea' in the rice field has opened eyes for its manifold advantages. USG dissolve slowly in soil providing a steady supply of available nitrogen throughout the growing period of crop thus crop satisfied with its demand during its different stages of growth. Placement of USG in the root zone of rice 8-10 cm depth of the soil (reduce zone of rice soil) is the most effective method for increasing the nitrogen use efficiency by keeping most of the urea nitrogen in the soil close to the plant roots and out of the flood water where it is more susceptible to loss as gaseous compounds or run off (Mohanty *et al.*, 1999). It is noted that using USG can save 30% nitrogen than prilled urea, increase absorption rate, improve soil health and ultimately increase the rice yield of about 30-40% (Savant *et al.*, 1991). Broadcast application of urea on the surface soil causes loss up to 50% but point placement of USG in 10 cm depth may result negligible loss and improve its use efficiency for better grain production (Crasswell and De Datta, 1980). It is also reported that use of USG in rice field can save 10-20% nitrogen fertilizer cost in upland crop (Anon., 2003).

The farmers are already using USG in *Boro* and T. *Aman* rice. In some areas it is also used in different upland vegetables and fruit crops such as brinjal, cabbage, cauliflower, tomato, banana etc. Therefore it is very essential to evaluate the efficacy of USG against prilled urea in mustard cultivation. Not yet any studies have been done in this respect.

Keeping all the points mentioned above, the present piece of research work was under taken with the following objectives:

- To assess the response of mustard towards placement method of Nitrogen (N).
- To evaluate the proper time of application of USG at optimum depth on the growth and yield performance of mustard.

Chapter 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

Rapeseed-mustard is one of the principle oil crops in Bangladesh. The proper fertilizer management accelerates its growth and influences its yield as well as oil content. The literatures cited here are pertaining to the effect of nitrogen on the yield and yield attributes of the crops belonging to the group rapeseed and mustard. Also, some research works relating to the effect of different form of nitrogen on growth and yield component of various crops specially rice are reviewed in this chapter.

2.1 Effect of different managements of nitrogen on growth attributes

2.1.1 Plant height

2.1.1.1 Effect of prilled urea

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

Singh *et al.* (2002) also reported that mustard plant height increased significantly with successive increase in nitrogen up to 120 kg ha^{-1}.

BARI (1999) conducted trial in two different regions of Bangladesh, at Joydebpur & Ishwardi to justify the effect of N on yield of mustard. The experiment conducted with 3 levels of nitrogen (0, 120, 160 k ha^{-1}) and plant height (cm) was found 87.78, 113.94, 106.46 at Joydebpur and 90.79, 118.46, 113.69 cm at Ishwardi respectively. The highest plant height was found in both the location at 120 Kg N ha^{-1}.

Islam and Mondal (1997) showed that application of nitrogen at the rate of 0, 100, 200, 300 kg ha^{-1}, the maximum plant height of rapeseed was found 93.6 cm at 300 kg N ha^{-1}.

2.1.1.2 Effect of USG

Alam (2002) conducted an experiment at the agronomy field laboratory, BAU, Mymensingh during the *boro* season with three varieties and four level of USG. He also increased plant height with the increase level of USG/4 hill.

Mishra *et al.* (1999) conducted a field experiment during 1994-95 in Bhubaneswar, Orissa, India, and reported that rice cv. Lalate was given 76 kg N ha^{-1} as USG at 0, 7 and 14 for 21 days after transplanting (DAT) and reported that USG application increased plant height.

Vijaya and Subbaiah (1997) conducted an experiment with rice and gave fertilizer @ 90 kg N ha^{-1} as prilled urea, large granules urea or urea super granules (USG) and 70 kg P_2O_5 ha^{-1} as single super phosphate or large di-ammonium phosphate, both applied by broadcasting or placement methods. They showed that plant height of rice increased with the application of USG and were greater with the deep placement method of application both N and P compared with broadcasting.

Singh and Singh (1986) reported that rice plant height increases significantly with the increase in the level and forms of nitrogen from 27 to 87 kg N ha^{-1}. Deep placement of urea super granules (USG) resulted in the highest plant height than prilled urea.

Rekhi *et al.* (1989) conducted an experiment on a sandy loamy soil with rice cv. PR106 providing 0, 37.5 or 75 or 112.5 kg N ha^{-1} as 15 N-labeled PU or USG. They noted that application of PU produced the highest plant height.

On the other hand, Rahman (2003) stated that in case of rice, plant height did not affected by the different level of USG.

2.1.2 Branches plant^{-1}

2.1.2.1 Effect of prilled urea

Singh *et al.* (2003) studied the effect of nitrogen rates (60, 120 and 180 kg ha^{-1}) and application of N application (row and even application) on the performance of indian mustard cv. Basanti. They found that N at 120 kg ha^{-1} produced higher number of branches per plant compared to 60 kg N ha^{-1}. The N level higher than 120 kg ha^{-1} did not increase the number of branches per plant.

Tripathi and Tripathi (2003) performed an experiment to investigate the effect of N levels (80, 120, 160 and 200 kg ha^{-1}) on the branches number of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and 60 days after sowing. Results showed that the number of primary branches per plant increased up to 200 kg N ha^{-1}.

Sharma and Jain (2002) conducted an experiment on mustard with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) in a cropping system and observed that 80 kg N ha^{-1} resulted the highest number of branches (24.4) per plant.

Shukla *et al.* (2002) conducted an experiment to study the integrated nutrient management for Indian mustard *(B. juncea)* and found that the highest number of branches per plant was obtained with the broadcast method of N application.

2.1.2.2 Effect of USG

Vijaya and Subbaiah (1997) stated that number of tillers in rice plant increased with the use of USG and were greater with the deep placement method of application comparing with N broadcasting.

Kamal *et al.* (1991) conducted a field experiment in *kharif* season of 1985 and 1986 on rice cv. Joya with different level of nitrogen @ 29, 58 and 87 kg ha^{-1} as urea super granules (USG). Among the three doses of nitrogen total tillers was the highest when 87 kg N ha^{-1} was applied. They also reported that productive tillers also higher with the same dose of nitrogen.

Jee and Mahapatra (1989) also observed that number of panicles per square meter in rice plant were significantly higher @ 90 kg N ha^{-1} as deep placed urea super granules (USG) than split application of urea.

Mirzeo and Reddy (1989) worked with different modified urea material and levels of N @ 30, 60 and 90 kg with rice. They reported that root zone placement of urea super granules (USG) produced the highest number of tillers at 30 or 60 days after transplanting. Urea super granules gave 14.0 and 8.8% more panicles per square meter in 1983 and 7.6 and 8.4% more panicles per square meter in 1984 than neem coated urea or prilled urea, respectively.

Rama *et al.* (1989) mentioned that in rice plant the number of panicles per square metre increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as different modified urea materials. Urea super granules (USG) produced significantly higher number of panicles per square meter and grains per panicle than split application of prilled urea.

2.1.3 9 Leaf area index and dry matter production

2.1.3.1 Effect of prilled urea

Sinha *et al.* (2003) fertilized rapeseed cv. B-9 plants with 0, 30, and 60 kg N ha^{-1} under irrigated or non-irrigated condition. They observed that dry matter accumulation increased with increasing rate of nitrogen.

Saikia *et al.* (2002) estimated that the total dry matter of Indian mustard significantly responded with the increasing levels of nitrogen (0, 30, 90, 120 and 150 kg ha^{-1}).

Shukla *et al.* (2002) conducted an experiment to study the integrated nutrient management for Indian mustard *(B. juncea).* They found highest total dry matter at harvest with the application of 120 kg N ha^{-1}.

Singh *et al.* (2002) also concluded that dry matter accumulation/plant increased significantly with successive increased in nitrogen up to 120 kg ha^{-1}.

2.1.3.2 Effect of USG

Miah *et al.* (2004) found that LAI of rice plant was significantly higher in USG receiving plots than urea at heading and the total dry matter production was affected notably by the use of USG. USG applied plots gave higher TDM compared to urea irrespective of number of seedling transplanted $hill^{-1}$.

Rambabu *et al.* (1983) stated that different forms and methods of application of N fertilizers to rice grown under flooded conditions, placement of N as USG (1 and 2 g size) in the root zone at transplanting was the most effective in increasing dry matter production and lowest with urea applied as a basal drilling.

2.2 Effect of different managements of nitrogen on yield attributes

2.2.1 Siliquae plant^{-1}

2.2.1.1 Effect of prilled urea

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}). He observed that adequate N fertilization is important in increasing the number of siliquae per plant and observed highest siliquae number per plant of summer oilseed rape at the rate of 160 kg N ha^{-1}.

Singh *et al.* (2003) conducted an experiment to study the effect of nitrogen rates (60, 120 and 180 kg ha^{-1}) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg ha^{-1} produced higher number of siliquae per plant (48.03). The N level higher than 120 kg ha^{-1} did not increase the number of siliquae significantly.

Sharma and Jain (2002) studied with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) along with the cropping system and found that the application of 80 kg N ha^{-1} produced the highest number of siliquae per plant of mustard.

Singh *et al.* (2002) also reported that in mustard siliquae per plant increased significantly with successive increase in nitrogen up to 120 kg ha^{-1}.

BARI (1999) reported 22.7, 42.0, 45.6 and 48.0 number of siliquae per plant of mustard with 0, 80,120 and 140 N kg ha^{-1}, respectively.

2.2.1.2 Effect of USG

BARI (2008) conducted several experiments to find out the effect of USG on various crops as brinjal, potato, hybrid maize etc. and established that these crops gives higher fruit per plant, tuber per haulm, cob per plant, respectively.

Nassem *et al.* (1995) conducted an experiment and found that percent grain remain unchanged in response to different levels of nitrogen.

Surendra *et al.* (1995) conducted an experiment during rainy season in rice plant with nitrogen level @ 0, 40, 80, 120 kg ha^{-1}. They showed that urea super granules produced significantly more panicle /hill, filled grains/ panicle, panicle weight and grain yield than prilled urea @ 80 kg N ha^{-1}.

Thakur (1991) studied the influence of levels, forms of urea and method of application of nitrogen in rice during kharif season. He observed that yield attributes and grain yield differed significantly due to the levels and sources of nitrogen applied. Placement of nitrogen at 60 kg N ha^{-1} through urea super granules (USG) produced the highest number of panicle /unit area, panicle weight, number of grains/ panicle, 1000-grain weight, which ultimately gave the highest grain yield of 4.77 t ha^{-1} in 1987 and 4.94 t ha^{-1} in 1988.

Jee and Mahapatra (1989) found that number of panicles m^{-2} were significantly higher @ 90 kg ha^{-1} as deep placement of urea super granules (USG) than split application of urea.

Rama *et al.* (1989) mentioned that the number of panicles m^{-2} increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as urea super granule (USG).

2.2.2 Seeds siliqua^{-1}

2.2.2.1 Effect of prilled urea

Sharma and Jain (2002) conducted an experiment with different levels of nitrogen and observed that the application of 80 kg N ha^{-1} resulted in the highest number seeds (15.3) per siliqua in mustard.

Shukla *et al.* (2002) conducted an experiment to study the effect of nitrogen for Indian mustard *(B. juncea).* They obtained maximum number of seeds per siliqua when 120 kg ha^{-1} nitrogen was applied.

Tarafder and Mondal (1990) reported from an experiment conducting for determining the effect of nitrogen and sulphur on seed yield of mustard (var. Sonali Sharisa) and found that the combine effect of nitrogen and sulphur fertilizers increased the number of seeds per siliqua.

Singh *et al.* (2002) conduct an experiment with Varuna variety of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}). They got vast increment of seeds per siliqua with the nitrogen level 60-120 kg ha^{-1}.

2.2.2.2 Effect of USG

BARI (2008) experimented to find out the effect of USG on hybrid maize and found that 10% less application of N than the recommended dose as USG gave the highest grain per cob (476) than prilled urea.

Reddy *et al.* (1986) reported that increasing N rates from 30 to 60 and 90 kg ha^{-1} increased paddy yields of wetland rice from 2.89 to 3.77 and 4.39 t ha^{-1} respectively. N as urea super granules (USG) placed in the root zone in soil gave significantly higher yields than other form of urea.

Petal and Desai (1987) carried out an experiment on rice applying N @ 58.87 or 16 kg ha^{-1} as sulphur coated urea, urea super granules (USG) and phosphorus coated urea. They reported 58.87 kg N ha^{-1} as urea super granules placed at 10-12cm depth gave the highest yield (4.34 t ha^{-1}) and number of panicles/ m^2.

2.2.3 1000-seed weight

2.2.3.1 Effect of prilled urea

Ozer (2003) studied two cultivars (Tower and Lirawell) of rapeseed to investigate the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}). He observed that adequate N fertilization was important in increasing 1000- seed weight in summer oilseed rape and suggested that the rate of 160 kg N ha^{-1} will be adequate for the crop to meet its N requirements. 1000-seed weight differs with nitrogen levels that enhanced yield.

Singh (2002) conducted an experiment with Varuna variety of mustard with 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and P (0, 15, 30, 45 and 60 kg ha^{-1}). Application of N and P increased 1000-seed weight. However, the significant increase in 1000 seed weight was recorded in 120 kg N ha^{-1}.

Sharma and Jain (2002) conducted an experiment of mustard with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} increased 1000-seed weight (3.55 g).

Shukla *et al.* (2002) conducted an experiment to study the integrated nutrient management for Indian mustard *(B. juncea).* They obtained maximum 1000-seed weight with the application of 120 kg N ha^{-1}.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased 1000-seed weight.

Shamsuddin *et al.* (1987) worked with mustard for five levels of nitrogen (0, 30, 60,90 and 120 kg N ha^{-1}) and four levels of irrigation and observed that 1000-seed weight increased progressively with the successive increase of N rate up to 120 kg ha^{-1}.

2.2.3.2 Effect of USG

Hasan *et al.* (2002) determined the response of hybrid (Sonar Bangla-1 and Alok 6201) and inbred (BRRI dhan 34) rice varieties to the application methods of urea super granules (USG) and prilled urea (PU) and reported that the effect of application method of USG and PU was not significant in respect of 1000-grain weight.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea super granules (USG) and broadcasting prilled urea (PU) as sources of N in T. *aman* rice. USG and PU were applied @ 40, 80, 120 or 160 Kg N ha^{-1}. They reported that USG was more efficient than PU on 1000-grain weight.

Roy *et al.* (1991) compared deep placement of urea super granules (USG) by hand and machine and prilled urea (PU) by 2 to 3 split applications in rainfed rice during 1986 and 1987. They reported that USG performed better than PU in all the parameters tested. Significant difference was observed in 1000-grain weight and highest grain weight was obtained from USG (by hand) treated plots.

Kamal *et al.* (1991) conducted a field experiment on rice cv. Joya in Kharif seasons of 1985 with different forms of urea and level of nitrogen. They reported that 1000-grain weight was not significantly influenced by the forms of urea.

Thakur (1991) studied the influence of levels, forms of urea and method of application of nitrogen in rice during Kharif season. He observed that yield attributes and grain yield differed significantly due to the levels and sources of nitrogen applied. Placement of nitrogen at 60 kg ha^{-1} through urea super granules (USG) produced the highest number of panicle /unit area, panicle weight, number of grains/ panicle, 1000-grain weight, which ultimately gave the highest grain yield of 4.77 t ha^{-1} in 1987 and 4.94 t ha^{-1} in 1988.

Alam (2002) conducted an experiment at the agronomy field laboratory, BAU, Mymenshing during the *boro* season with three varieties and four level of USG. He observed that 1000-grain weight was not influenced by level of USG.

2.2.4 Seed yield

2.2.4.1 Effect of prilled urea

Arthamwar *et al.* (1996) conducted an experiment with mustard variety (Pusa Bold and T-59) having 3 levels of N (0, 50 and 100 kg). Result showed that highest seed yield obtained with N at 100 kg ha^{-1} (1.20 t ha^{-1}).

BARI (1999) investigated 4 levels of nitrogen as 0, 80,120,140 kg ha^{-1} on different varieties of mustard and yields were found correspondingly 493.3, 833.3, 940.0, 993.7 kg ha^{-1}.

Davaria and Mehta (1995) also reported that increasing nitrogen rate from 25 to 75 kg ha^{-1} increased seed yield from 2.07 - 2.41 t ha^{-1}.

Hossain and Gaffer (1997) conducted a trial with 5 levels of nitrogen at 0, 100, 150, 200, 250 kg ha^{-1} on rapeseed and maximum yield was found 1.73 t ha^{-1} with 250 kg N ha^{-1}.

Kumar and Singh (2003) reported significant increase in seed yield (1.6 t ha^{-1}) with nitrogen at 150 kg ha^{-1}.

Ozer (2003) studied the effect of sowing dates with four levels of nitrogen (0, 80, 160 and 240 kg N ha^{-1}) on two cultivars of rapeseed. He observed that adequate N fertilization is important in yield formation in summer oilseed rape and suggested that the rate of 160 kg N ha^{-1} will be about adequate for the crop to meet its N requirements.

Sharma and Jain (2002) conducted an experiment with five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) followed by the cropping system that the application of 80 kg N ha^{-1} resulted in the highest seed yield (1649.22 kg ha^{-1}). The highest values of seed yield and yield attributes were recorded for *S. canabina* - Indian mustard receiving 80 kg N ha^{-1}.

Shukla *et al.* (2002) also conducted an experiment to investigate the effect of S (0 or 40 kg ha^{-1}) and N (60, 90 or 120 kg ha^{-1}) on the yield and yield attributes of rape cultivars. Sulphur did not significantly affect the seed yield and yield attributes. However, N at 120 kg ha^{-1} produced higher seed yield than N at 60 and 90 kg ha^{-1}.

Sidlauskas (2000) found that the yield of rapeseed was increased with the increasing rate of nitrogen levels up to 120 kg ha^{-1}. Further increase of nitrogen level did not affect the seed yield.

Singh (2002) conducted a study with variety Varuna of mustard having 5 levels of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) and P (0, 15, 30, 45 and 60 kg ha^{-1}). Application of N increased the seed yield. However, the significant increase in seed yield was recorded in 60-120 kg N ha^{-1}.

Singh and Prasad (2003) reported that 120 kg N ha^{-1} as prilled urea gave the highest seed yield (20.24 q ha^{-1}) in mustard.

Singh and Saran (1989) set an experiment with *Brassica campestris* var. Toria and applied different doses of nitrogen. They found that nitrogen at the rate of 60 kg ha^{-1} increased the seed yield. This dose gave seed yields of 1.20 t ha^{-1} compared to 0.89 t ha^{-1} without nitrogen.

Singh *et al.* (2003) reported from an experiment conducting for determining the effect of nitrogen rates (60, 120 and 180 kg ha^{-1}) on the performance of Indian mustard cv. Basanti. They observed that N at 120 kg ha^{-1} produced higher seed yield (2.55q ha^{-1}) compared to 60 kg N ha^{-1}. The N level higher than 120 kg ha^{-1} did not increase the yield significantly.

Sinsinwar *et al.* (2004) observed the increased seed yield of Indian mustard with each increment of N fertilizer up to 60 kg ha^{-1} beyond this the increase was marginal. On an average, the increase in seed yield compared to the control was 33.3 and 83.8% with 30 and 60 kg N ha^{-1}.

Tripathi and Tripathi (2003) performed an experiment to inspect the effect of N levels (80, 120, 160 and 200 kg ha^{-1}) on the yield of Indian mustard cv. Varuna. Nitrogen was applied at 3 equal splits, at sowing, at first irrigation and 60 days after sowing. Results showed that seed yield increased with increasing N levels up to 160 kg N ha^{-1}.

Zhao *et al.* (1997) reported that, the seed yield of rapeseed (0.88 t ha^{-1}) was obtained at a nitrogen fertilization of 90 kg ha^{-1}.

2.2.4.2 Effect of USG

Miah *et al*. (2004) observed that the seed yield was higher with application of urea super granules compared to application of urea.

Jaiswal and Singh (2001) conducted a field experiment on comparative efficiency of urea super granules and prilled urea, both at 60 and 120 kg ha^{-1} on rice cultivation under different planting method during 1996-97 and 1997-98, in Faizabad, Uttar Pradesh, India. They stated that transplanting method with USG placement proved to be best for maximum grain yield (4.53 t ha^{-1}) and deep placement of USG increased N use efficiency (31.7%) compared to conventional method of urea application.

Das and Singh (1994) pointed out grain yield of rice cv. RTH-2 during Kharif season was greater for deep placed urea super granules (USG) than urea super granules for broadcast and incorporated or three split applications of prilled urea.

Singh and Singh (1993) pointed out that application of 30 or 60 kg N ha^{-1} as prilled urea or urea super granules (USG) gave the highest grain yield. N uptake increased with the rate of N application and was highest with deep placed urea super granules. N use efficiency was the highest with 30 kg N ha^{-1} from deep placed urea super granules.

Johnkutty and Mathew (1992) conducted an experiment with different forms of nitrogen on rice cv. Jyothy during rainy season and reported that 84 kg N ha^{-1} as urea super granules (USG) gave higher yield than urea.

Ameta and Singh (1990) observed that increasing N fertilizer application from 30 to 120 kg ha^{-1} increased rice grain yield linearly from 3.52 to 5.36 t ha^{-1}. Coating urea with neem cake powder

(20% by weight) at transplanting, tillering and panicle initiation stages produced grain yield of 4.87 t ha^{-1} compared to 4.39 t ha^{-1} from applying all N as basal dressing. Placement of 75 kg urea super granules (USG) at 8-10cm soil depth, 7 days after transplanting produced similar grain yield as application of 90 kg plain urea.

Chalam *et al.* (1989) reported that the application of N @ 37.5, 75.0 or 112.5 kg ha^{-1} as urea super granules (USG) or prilled urea gave paddy yields of 3.15-3.53, 4.06-4.32 and 3.66-3.75 t ha^{-1} compared with 2.20 t ha^{-1} without nitrogen. Yields, N uptake and N recovery percentage were higher with N as urea super granules than prilled urea.

Chauhan and Mishra (1989) found that application of N @ 20, 80 and 112 kg ha^{-1} as urea super granules (USG) gave grain yield 4.08, 4.86 and 5.17 t ha^{-1} and as prilled urea gave 3.95, 3.72 and 4.33 t ha^{-1}, respectively. Deep placement of urea super granules proved superior to prilled urea.

Mirzeo and Reddy (1989) reported that deep placement of urea super granules gave 10.3% more grain yield than prilled urea or neem coated urea.

Patel and Desai (1987) found that rate of 58 kg N ha^{-1} as urea super granules placed at 10-12 cm depth gave the highest yield (4.34 t ha^{-1}) compared to any other rate.

Raju *et al* (1987) conducted an experiment during Kharif with different sources of N fertilizers @ 0, 37.5, 75, 112.5 and 150 kg N ha^{-1}. They reported that among all the sources of N, urea super granules (USG) recorded highest grain yield (5.41 t ha^{-1}) and proved significantly superior to rest of the sources. The increase in yield due to urea super granules over urea split application was to the tune of 14.7%. The rest of the N sources failed to exert any differential effect on yield.

Nayak *et al.* (1986) carried out an experiment under rainfed low land conditions with the amount of 58 kg N ha^{-1} as urea super granules (USG) placed in the root zone. They showed that USG was significantly superior to N as sulphur coated urea (SCU) or urea applying in split dressing, increasing panicle production /unit area and yields.

Reddy *et al.* (1986) reported that increasing N rates from 30 to 60 and 90 kg ha^{-1} increased paddy yields of wetland rice from 2.89 to 3.77 and 4.39 t ha^{-1} respectively. Nitrogen as urea super granules (USG) placed in the root zone in soil gave significantly higher yields than N as neem cake coated urea (NCCU), urea dicyandiamide incorporated urea.

Sen *et al.* (1985) conducted an experiment under irrigated wetland conditions in the rainy season in 1982 and 1983. They reported that the placement of urea super granules (USG) at any time between 0 and 20 days after transplanting and in placement at 0, 5 and 10 days after transplanting gave similar yields. The average increase in yield from urea super granules placement compared with urea alone in 3 split dressing was about 46% in 1982 and 20% in 1983. All yield components were positively correlated with yield.

Apparao (1983) pointed out that deep placement of 50 kg N ha^{-1} as urea super granules (USG) gave significantly higher paddy yields compared with urea applied basally or in 3 split applications.

2.2.5 Stover yield

2.2.5.1 Effect of prilled urea

Prasad *et al.* (2003) reported the effect of N, S and Zn fertilizers on the nutrient uptake, quality and yield of Indian mustard cv. Vaibhav. The application of 60 kg N + 30 kg P + 20 kg S + 5 kg Zn and 60 kg N + 30 kg P + 20 kg S gave the highest stover yield (33.08 q ha^{-1}).

Singh and Prasad (2003) mentioned that 120 kg N ha^{-1} gave the highest stover yield (12.22 q ha^{-1}).

Meena *et al.* (2002) conducted an experiment to study the effect of nitrogen, irrigation and intercultural operation on yield and yield attributes of mustard. The results of experiment revealed that the application of 60 kg N ha^{-1} registered significantly higher stover yield of mustard over control.

Singh *et al.* (2002) reported that stover yield increased significantly with successive increase in nitrogen up to 120 kg ha^{-1}.

2.2.5.2 Effect of USG

Singh and Singh (1988) pointed out that deep placement of urea super granules (USG) was superior in grain and straw yield, nitrogen uptake and nitrogen use efficiency to that of prilled urea.

Bharat and Srivastava (1989) conducted a field experiment in Kharif season on rice cv. Java was given @ 0, 29, 58, 87 or 116 kg N ha^{-1} as prilled urea or urea granules (USG). They obtained grain yield 2.14 and 2.68 t ha^{-1}, respectively. N uptake in grain and straw increased with the N application rate and was higher with urea super granules.

Das (1989) reported that the dry matter yield, concentration of NH_4^+ N content in soil, N uptake and grain and straw yield of rice were higher with application of urea super granules (USG).

Quayum and Prasad (1994) conducted field trials during Kharif season with 5 rates of N (0, 37.5, 75, 112.5 and 150 kg ha^{-1}) and six different sources of Nitrogen with rice cv. Sita and found that application of up to 112.5 kg N ha^{-1} increased grain (4.37 t ha^{-1}) and straw yields (5.49 t ha^{-1}). They also reported that N as USG gave the best yield and concluded that slow release fertilizers were effective for rainfed lowland rice.

Mohanty *et al.* (1989) observed that placement of USG in rice gave significantly higher grain and straw yields of 36 and 39% in dry and 17 and 18% in wet season, respectively than split application of PU.

From the reviews cited and discussed above, it can be concluded that nitrogenous fertilizer as prilled urea, urea super granules (USG) etc. play a remarkable role for the growth, yield and yield components of mustard and other crops. Use of USG on mustard crop could be another economic way of improving yield of mustard.

Chapter 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during November-February, 2009-2010. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recordings and their analyses.

3.1 Site description

The experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka, at 23º 74′ N latitude and 90 º 35′ E longitudes with an elevation of 8.2 meter from sea level. The experimental field is a medium high land belongs to the agro-ecological zone (AEZ-28) of Madhupur Tract. The soil texture of experimental site was silty loam. The field contained low organic matter content with low N, K, S etc. The experimental site has been shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area was under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during the rabi season (October-March). The maximum and minimum air temperature varied as 25.4-29.6 and 12.7-19.0, respectively during experimental period (November- December, 2009-2010), relative humidity, total rainfall and sun shine hour were found as 68-77%, 7.7-34.4 mm and 5.5-5.7, respectively (Appendix II).

3.3 Soil

The soil of the experimental field belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunlight was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field.

3.4 Collection and preparation of initial soil sample

The initial soil samples from the main field were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis. The analyses were done from Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical property of the soil has been presented in Appendix III.

3.5 Planting material

A high yielding variety of mustard, BARI Sarisha-14(*Brassica campestris*) was used as test crop. It is bold and yellow colored seeded. This mustard variety tested against nitrogen (N) fertilizer placement. Required seed was collected from Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

3.6 Fertilization

Granules urea or prilled urea (PU) and urea super granules (USG) were used at the rate of 300 kg ha^{-1} and 142.86 kg ha^{-1} (2.7 g per granules), respectively.

Prilled Urea: It is the most common form of urea available in the market. It contains 46% N. The mean diameter of urea aggregates is 1.5 mm.

Urea Super Granule: Urea super granule fertilizer is manufactured by physical modification of granules urea. It has been developed by the IFDC, Muscle Shoals, Alabama and USA. It is well recognized as a slow release nitrogenous fertilizer containing 46% N. Its nature and properties are similar to that of urea but its granule size is bigger, condensed with some conditions for slow hydrolysis as it is deep placed. The weight of used individual granule in this experiment was 2.7 g approximately.

3.7 Experimental treatments:

The experiment consisted of the following treatments:

T_1= Prilled Urea (PU) broadcasted (conventional method)

T_2= PU given in the side furrows

T_3= PU given between two rows

T_4=PU and seed given in the same furrows

T_5= Urea Super Granules (USG) placed at 5 cm depth as basal

T_6= USG placed at 5 cm depth at 10 days after sowing (DAS)

T_7= USG placed at 5 cm depth at 20 DAS

T_8= USG placed at 5 cm depth at 30 DAS

T_9= USG placed at 10 cm depth as basal

T_{10}= USG placed at 10 cm depth at 10 DAS

T_{11}= USG placed at 10 cm depth at 20 DAS

T_{12}= USG placed at 10 cm depth at 30 DAS

T_{13}= USG placed at 15 cm depth as basal

T_{14}= USG placed at 15 cm depth at 10 DAS

T_{15}= USG placed at 15 cm depth at 20 DAS

T_{16}= USG placed at 15 cm depth at 30 DAS

3.8 Design and layout of the experiment

The experiment was laid out in a Randomized complete block design (RCBD) with three replications. Each replication was divided into sixteen plots where different nitrogen application methods were assigned in different plots. The total number of plot was 48 (16 treatments × 3 replications). The layout of the experiment has been shown in Appendix IV

Plot Details

Plot size- 4.25 × 2.5 m^2

Plot to plot distance- 0.75 m

Replication to replication distance- 1.5 m

3.9 Crop production practices

3.9.1 Preparation of main land for sowing

The experimental field was first opened on 1st November, 2009 with the help of a disc plough and prepared by three successive ploughing and cross-ploughing. Each ploughing was followed by laddering to have a good tilth. The corners of the land were spaded. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 9th November, 2009 according to the design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden ladder. On 10th November, 2009 basal fertilizing and sowing were done following the treatment variables.

3.9.2 Fertilizer application

Basal application

The experimental field was divided into 48 plots. Every plot was given recommended fertilizer dose @ 180-100-180 kg ha^{-1} of TSP, MP and Gypsum. Treatment T_1- T_4 was fertilized with half recommended dose of prilled urea where rest half was applied at 30 DAS and treatment T_5-T_{16} was fertilized with urea super granules (USG).

Placement of urea super granules

Nitrogen application in the form of USG was applied in plots as per treatments.

3.9.3 Sowing

3 kg ha^{-1} seeds were sown in line as recommendation.

3.9.4 Intercultural operations

The following intercultural operations were done for ensuring normal growth of the crop-

Thinning

Three times thinning was done at 10, 20 and 30 DAS to maintain uniform plant population in each plot.

Weeding

During plant growth period three hand weeding were done 10, 20 and 30 DAS.

Irrigation and drainage

Irrigation was given four times during crop growing period. First post sowing and the rest at 10, 30 and 40 DAS. First three was pipe irrigation and last one was flood irrigation. The drainage system was well prepared and thus excess water drained easily.

Plant protection measures

Sevin (1 lb/acre) was incorporated in soil at 10 DAS to save plant from insect attack.

3.9.5 General observation of the experimental field

The field was observed regularly from germination to till harvesting. It was a nice view to look at the green plants at initial stage and yellow flowers at later stage. Throughout the growing period no major insect, pest and diseases was observed.

3.9.6 Sampling and harvesting

Ten plants from each plot were randomly collected for growth analysis at 15 days interval started from 15 DAS. For final data collection 3 m^2 areas from the middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording data on yield component, yield and straw yield. Maturity of crop was determined when 90% of the plants became golden yellow in color. The harvesting was done at full maturity on 19th February 2010. Threshing was done manually. The seeds were cleaned and sun dried to a moisture content of 10%. Stover was also sun dried properly. Seed and stover yields $plot^{-1}$ were converted to t ha^{-1}.

3.10 Collection of data

A. Crop growth characters

- Plant height (cm)
- Leaf Area index
- Branch plant^{-1}(no.)
- Above ground dry matter plant^{-1} (g)

B. Yield contributing characters

- Siliquae plant^{-1}(no.)
- Seeds siliqua^{-1}(no.)
- 1000 seed weight (g)

C. Yield

- Seed yield (t ha^{-1})
- Straw yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Harvest index (%)

3.11 Experimental measurements

Growth data collection on growth parameters started at 15 days after sowing, and continued till harvest at 15 days interval. Data on agronomic characters were collected from ten randomly selected plants from each plot in the field and at harvest.

Plant height (cm)

Plant height was measured at 15 days interval and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before flowering, and to the tip of inflorescence after flowering and averaged.

Leaf area index (LAI)

Leaf area index was determined using a meter (Model- CI-202, Version- 3.06) and expressed as per plant basis.

Branches plant^{-1} (no.)

Number of branches plant^{-1} was counted starting from 45 DAS with 15 days interval up to harvest and expressed as per plant basis.

Dry matter weight plant^{-1} (g)

The samples of 10 plants plot^{-1} was uprooted from the plots excluding boarder plants and were oven dried until a constant level from which the weight of above ground dry matter was recorded and then converted to per plant basis.

Siliquae plant^{-1} (no.)

Ten plants are collected from each plot and number of siliquae and averaged for per plant basis.

Seeds siliqua^{-1} (no.)

Twenty siliquae were collected from total siliquae of a plant and total seeds were recorded. Final data was an average of seeds per siliqua from different plants.

Weight of 1000-seed (g)

One thousand cleaned dried seeds were counted randomly from each plot and weighed by using a digital electric balance at the stage when grain retained 10% moisture and the mean weight were expressed in gram.

Seed yield (t ha^{-1})

Seed yield was determined from the central 3 m^2 marked in each plot and converted to t ha^{-1} on 10% moisture basis.

Straw yield (t ha^{-1})

Straw yield was determined from the central 3 m^2 of each plot. After threshing, the samples were oven dried to a constant weight and finally converted to t ha^{-1}.

Biological yield (t ha^{-1})

The biological yield was calculated with the following formula-

Biological yield= Grain yield + Straw yield

Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated following (Gardner *et al.*, 1985).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.12 Statistical Analysis of the Data

Collected data was analyzed by following the ANOVA technique using statistical program MSTAT-C and mean differences was adjudged with LSD at 5% level of significance.

Chapter 4

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, experimental results pertaining to the effect of different management methods of nitrogen on the growth and yield of mustard cv. BARI Sarisha-14 have been presented along with discussion in this chapter. Two forms of nitrogen fertilizer were used in this experiment as- PU (300 kg ha^{-1}) and USG (142.86 kg ha^{-1}).

4.1 Effect of different application methods of nitrogen on growth attributes

4.1.1 Plant height (cm)

The plant height of mustard cv. BARI Sarisha-14 was significantly influenced with the application methods of nitrogen fertilizer (figure-1 & appendix-V). It was observed that in case of plant height significant difference was found at 15, 30, 45, 75 DAS and at harvest but was insignificant only at 60 DAS.

At 15 DAS, highest plant height (7.35 cm) was found with broadcast application of prilled urea (T_1) which was statistically similar with treatment T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_7 (USG placed at 5 cm depth at 20 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS) T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{15} (USG placed at 15 cm depth at 20 DAS).

The lowest plant height (5.54 cm) was observed with T_{16} (USG placed at 15 cm depth at 30 DAS).

At 30 DAS, maximum plant height (19.11 cm) was found in T_3 (PU given between two rows) which was statistically at par with T_1 (PU broadcasted (Conventional method)), T_2 (PU given in the side furrows), T_4 (PU and seed given in the same furrows), T_6 (USG placed at 5 cm depth at 10 DAS), T_{10} (USG placed at 10 cm depth at 10 DAS) and T_{11} (USG placed at 10 cm depth at 20 DAS). The lowest plant height (13.24 cm) was found with T_8 (USG placed at 5 cm depth at 30 DAS) and was at par with T_2 (PU given in the side furrows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_7 (USG placed at 5 cm depth at 20 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS), T_{15} (USG placed at 15 cm depth at 20 DAS) and T_{16} (USG placed at 15 cm depth at 30 DAS).

At 45 DAS, the maximum height (61.11 cm) was observed at T_6 (USG placed at 5 cm at 10 DAS). Similar results were found for treatment T_1 (PU broadcasted (conventional method)), T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_7 (USG placed at 5 cm depth at 20 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{15} (USG placed at 15 cm depth at 20 DAS). Lowest plant height was found for T_{16} (USG placed at 15 cm depth at 30 DAS) which was statistically similar with T_1 (PU broadcasted (conventional method)), T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_5 (USG placed at 5 cm depth as basal), T_7 (USG placed at 5 cm depth at 20 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{15} (USG placed at 15 cm depth at 20 DAS).

At 60 DAS, there was no significant effect on plant height among the treatments. However, numerically the highest plant height (74.00 cm) was recorded at T_2 (PU given in the side furrows) and lowest (64.11 cm) at T_8 (USG placed at 5 cm depth at 30 DAS).

At 75 DAS, significant difference was found. T_3 (PU given between two rows of mustard) have the tallest plant (77.44 cm) and that was at par with T_1 (PU broadcasted (conventional method)), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_7 (USG placed at 5 cm depth at 20 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{15} (USG placed at 15 cm depth at 20 DAS). The lowest plant height (61.33 cm) was noted in T_{16} (USG placed at 15 cm depth at 30 DAS) followed by T_1, T_2 and T_4-T_{15}.

At harvest, there was significant variation among the treatments. The tallest plant height (86.80 cm) was found at T_4 (PU and seed given in the same furrows) followed by T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_4 (PU and seed placed in the same furrows),

T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_7 (USG placed at 5 cm depth at 20 DAS) and T_{13} (USG placed at 15 cm depth as basal). The shortest plant height was observed at T_{12} (USG placed at 10 cm depth at 30 DAS) and was at par with T_1-T_3, T_6, T_8-T_{11} and T_{13}-T_{16}.

From figure-1 it was revealed that PU with different application methods showed highest plant height at all the growth stage except 45 DAS. These findings are in harmony with Islam and Mondal (1997) who reported that the maximum plant height was found 93.6 cm at 300 kg N/ha. The plant height was not affected by the different level of USG reported by Rahman (2003). Rekhi *et al* (1989) did an experiment on a sandy loam soil with rice plant providing 112.5 kg N ha^{-1} as 15 N-labeled PU or USG and reported that application of PU produced the highest plant height.

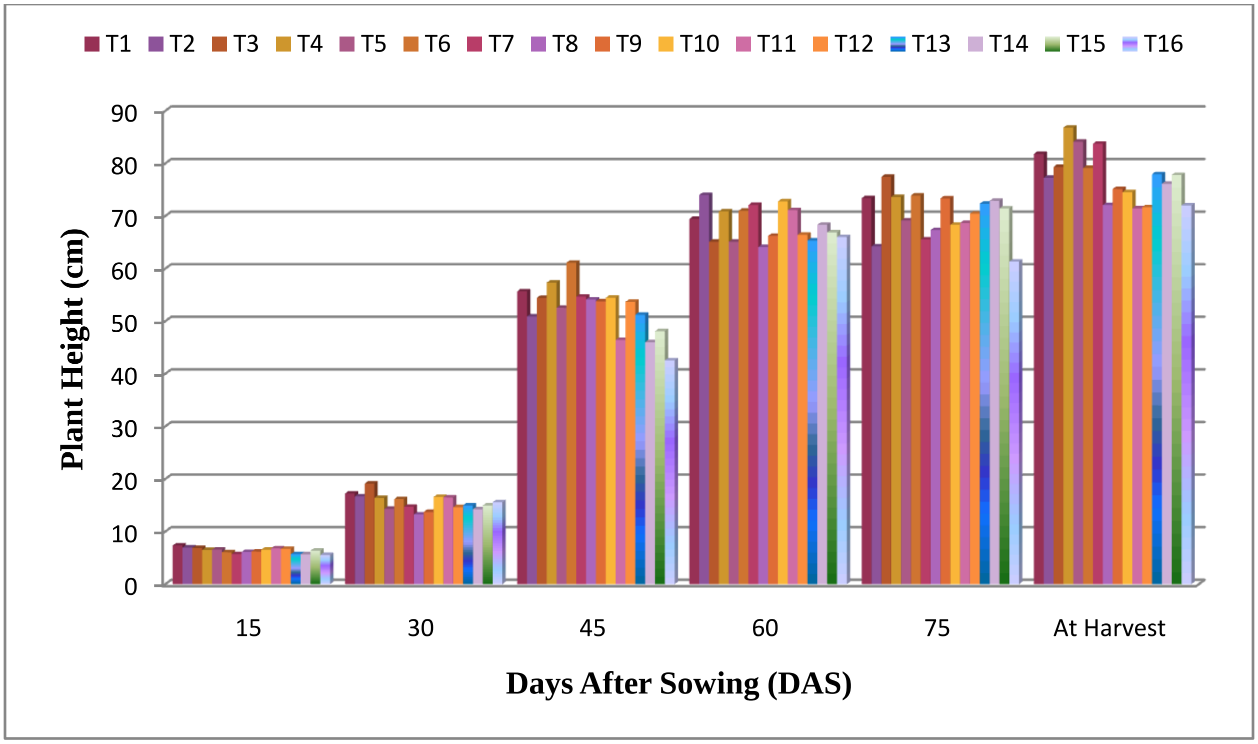


Figure 1. Plant height of mustard as influenced with application methods of nitrogen at different DAS (LSD $_{0.05}$ = 1.46, 2.98, 11.75, 9.31, 10.96 and 8.79 at 15, 30, 45, 60, 75 DAS and harvest, respectively)

T_1= PU broadcasted (conventional method)
T_2= PU given in the side furrows
T_3= PU given between two rows
T_4= PU and seed given in the same furrows
T_5= USG placed at 5 cm depth as basal
T_6=USG placed at 5 cm depth at 10 DAS
T_7= USG placed at 5 cm depth at 20 DAS
T_8= USG placed at 5 cm depth at 30 DAS
T_9= USG placed at 10 cm depth as basal
T_{10}= USG placed at 10 cm depth at 10 DAS
T_{11}= USG placed at 10 cm depth at 20 DAS
T_{12}= USG placed at 10 cm depth at 30 DAS
T_{13}= USG placed at 15 cm depth as basal
T_{14}= USG placed at 15 cm depth at 10 DAS
T_{15}= USG placed at 15 cm depth at 20 DAS
T_{16}= USG placed at 15 cm depth at 30 DAS

4.1.2 Branches plant^{-1} (No.)

Nitrogen management had significant effect on number of branches plant^{-1} (Figure-2 and Appendix-VI). At 60 DAS, T_4 (PU and seed in same furrows) produced the highest (5.55) branches plant^{-1} that was similar with T_1 (PU broadcasted (conventional method)), T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_7 (USG placed at 5 cm depth at 20 DAS), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{14} (USG placed at 15 cm depth at 10 DAS), T_{15} (USG placed at 15 cm depth at 20 DAS) and T_{16} (USG placed at 15 cm depth at 30 DAS). On the other hand, the lowest (1.94) was observed at T_8 (USG placed at 5 cm depth at 30 DAS). No significant difference was found at 75 DAS but variation was observed at harvest. Highest branches plant^{-1} (6.86) was produced at T_7 (USG placed at 5 cm depth at 20 DAS) followed by T_1- T_6 and T_9-T_{15}. The lowest (4.53) branches per plant was found at T_{16} (USG placed at 15 cm depth at 30 DAS). Increased number of branches in USG than PU might be due to uniform uptake of N by plant as it required. Similar result was reported by Vijaya and Subbaiah (1997). They found increased number of tiller per plant with the deep placement of USG.

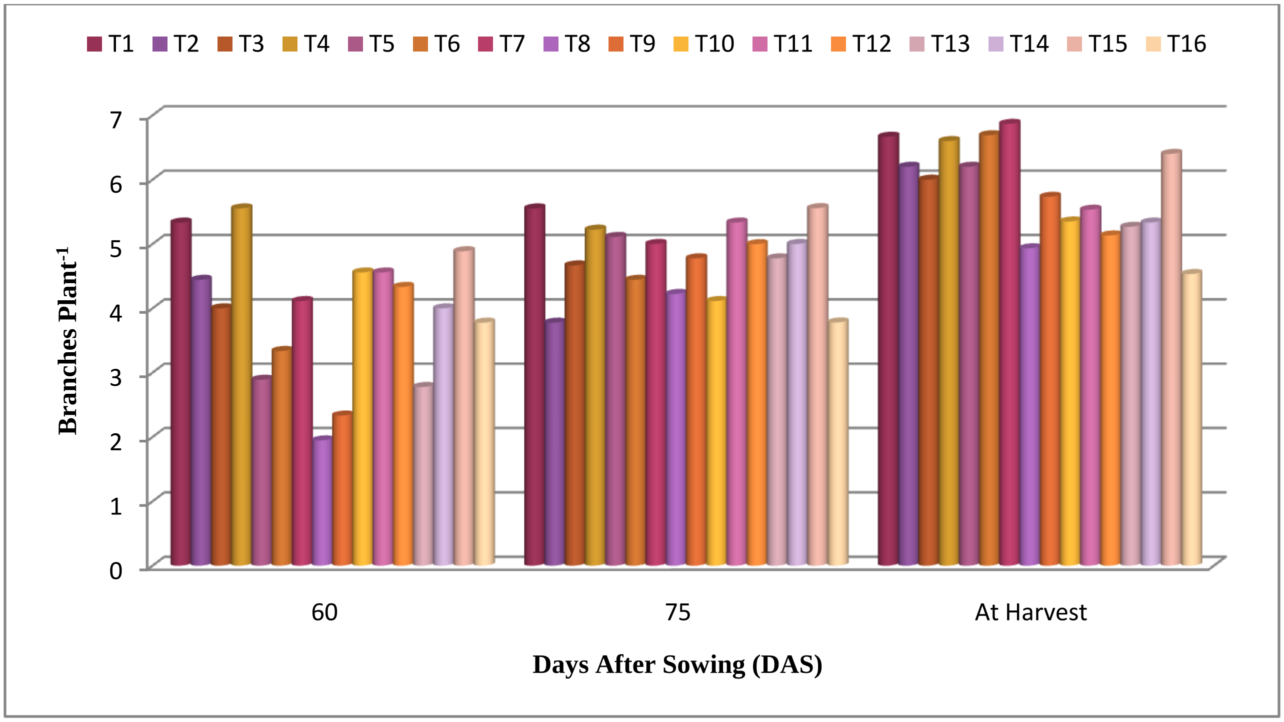


Figure 2. Effect of nitrogen application methods on the branches plant^{-1} (no.) of mustard at different days after sowing (LSD $_{0.05}$ =1.520, 1.667 and 2.301 at 60, 75 and at harvest, respectively)

T_1= PU broadcasted (conventional method)
T_2= PU given in the side furrows
T_3= PU given between two rows
T_4= PU and seed given in the same furrows
T_5= USG placed at 5 cm depth as basal
T_6=USG placed at 5 cm depth at 10 DAS
T_7= USG placed at 5 cm depth at 20 DAS
T_8= USG placed at 5 cm depth at 30 DAS
T_9= USG placed at 10 cm depth as basal
T_{10}= USG placed at 10 cm depth at 10 DAS
T_{11}= USG placed at 10 cm depth at 20 DAS
T_{12}= USG placed at 10 cm depth at 30 DAS
T_{13}= USG placed at 15 cm depth as basal
T_{14}= USG placed at 15 cm depth at 10 DAS
T_{15}= USG placed at 15 cm depth at 20 DAS
T_{16}= USG placed at 15 cm depth at 30 DAS

4.1.3 Leaf area index (LAI)

Among all the growth characteristics leaf area is one of the key determinants for crop yield. LAI of mustard varied significantly varied for different nitrogen managements at different growth stages. The LAI as a normal phenomenon increased with the advancement of plant age and declined after attaining its maximum value with time.

The trends of LAI at 15, 30, 45 and 60 DAS were more or less similar (Figure-3, Appendix-VII) due to the highest LAI was found with T_7 (USG placed in 5 cm depth at 20 DAS) that were 1.08, 1.99, 2.78 and 3.55, respectively. These finding was an accord with Ali (2005) and Miah *et al.* (2004) reported that LAI higher values of LAI in USG receiving plants than urea.

At 15 DAS, highest LAI was found at T_7 which was statistically similar at T_1 (PU broadcasted (conventional method)), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal) and T_{13} (USG placed at 15 cm depth as basal). The lowest LAI was found at T_{15}= USG placed at 15 cm depth at 20 DAS. That was followed by treatments T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_6 (USG placed at 5 cm depth at 10 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{16} (USG placed at 15 cm depth at 30 DAS)

At 30 DAS, maximum LAI was recorded in T_7 which was statistically similar with T_1 (PU broadcasted (conventional method)). The lowest LAI was found in T_{15} (USG placed at 15 cm depth at 20 DAS) that was statistically similar with T_2 (PU given in the side furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{16} (USG placed at 15 cm depth at 30 DAS)

At 45 DAS, the highest LAI was found only in T_7 and statistically similar lowest LAI was observed in T_{15} (USG placed at 15 cm depth at 20 DAS).

At 60 DAS maximum LAI was also recorded in T_7 which was statistically similar with T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS) and T_{13} (USG placed at 15 cm depth as basal). The lowest LAI was found in T_2 (PU given in the side furrows) and that is followed by treatment T_1 (PU broadcasted (conventional method)), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS), T_{15} (USG placed at 15 cm depth at 20 DAS) and T_{16} (USG placed at 15 cm depth at 30 DAS).

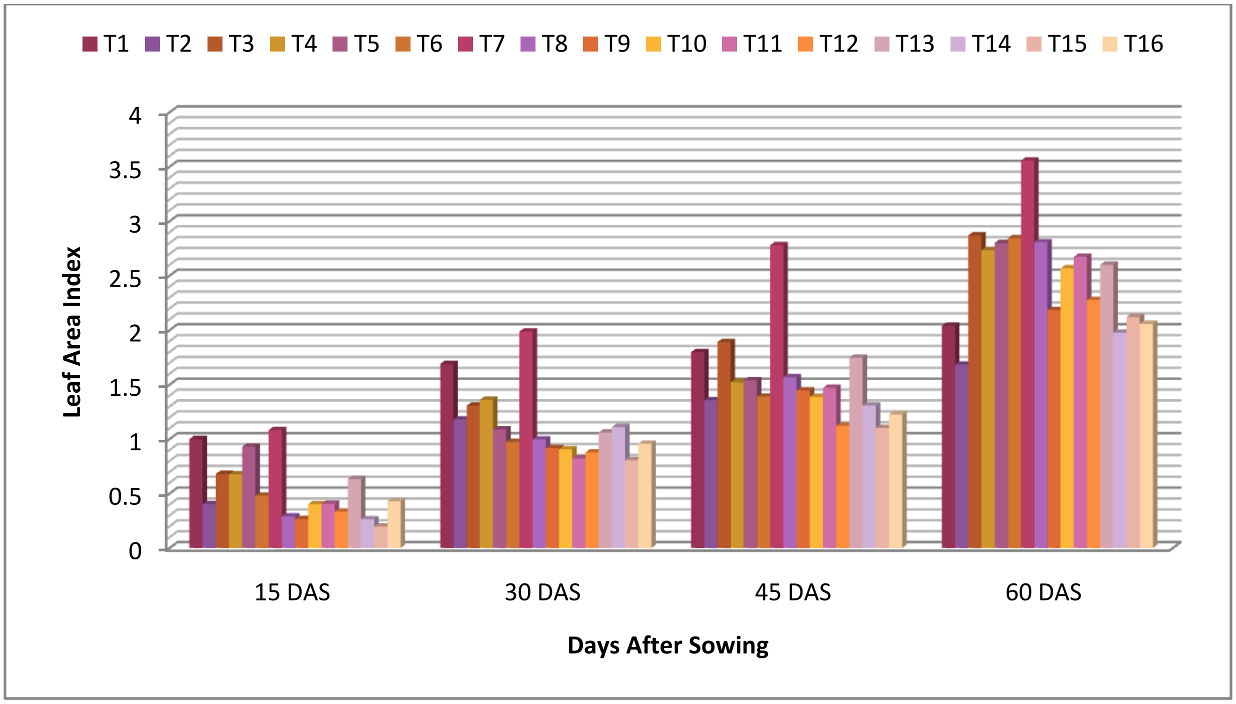


Figure 3. Leaf area index of mustard plant at various DAS as affected by different application methods of nitrogen ($LSD_{0.05}$ = 0.46, 0.39, 0.68 and 1.06 at 15, 30, 45 and 60 DAS respectively)

T_1= PU broadcasted (conventional method)
T_2= PU given in the side furrows
T_3= PU given between two rows
T_4= PU and seed given in the same furrows
T_5= USG placed at 5 cm depth as basal
T_6= USG placed at 5 cm depth at 10 DAS
T_7= USG placed at 5 cm depth at 20 DAS
T_8= USG placed at 5 cm depth at 30 DAS
T_9= USG placed at 10 cm depth as basal
T_{10}= USG placed at 10 cm depth at 10 DAS
T_{11}= USG placed at 10 cm depth at 20 DAS
T_{12}= USG placed at 10 cm depth at 30 DAS
T_{13}= USG placed at 15 cm depth as basal
T_{14}= USG placed at 15 cm depth at 10 DAS
T_{15}= USG placed at 15 cm depth at 20 DAS
T_{16}= USG placed at 15 cm depth at 30 DAS

4.1.4 Above ground dry matter (g plant^{-1})

The dry matter production in plant was very slow at early growth stage (15 to 45 DAS) than sharply increased from 60 DAS to harvest. Dry matter production exerted significant difference due to managements (Figure-4 and Appendix-VIII) at all growth stages.

At 30 DAS, T_6 (USG at 5 cm depth at 10 DAS) produced the highest 0.39 g above ground dry matter plant^{-1} and was statistically similar with T_1 (PU broadcasted (conventional method)), T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_8 (USG placed at 5 cm depth at 30 DAS), T_9 (USG placed at 10 cm depth as basal), T_{12} (USG placed at 10 cm depth at 30 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{15} (USG placed at 15 cm depth at 20 DAS) and T_{16} (USG placed at 15 cm depth at 30 DAS). The lowest dry matter was found at T_{11} (USG placed at 10 cm depth at 20 DAS) that was followed by T_1-T_5 and T_7-T_{16}.

At 45 DAS highest dry matter was observed at T_6 (USG placed at 5 cm depth at 10 DAS) and was 1.6 g that was statistically similar with T_1-T_5 and T_7-$T_{15.}$ The lowest 0.59 g was found at T_{16} (USG placed at 15 cm depth at 30 DAS) that was at par with T_1-T_3, T_5, T_7 and T_{10}-$T_{15.}$

At 60 DAS highest dry matter was observed at T_2 (PU given in the side furrows) and lowest was found at T_9 (USG placed at 10 cm depth as basal).

At 75 DAS highest dry matter (11.94 g) was produced at T_6 (USG placed at 5 cm depth at 10 DAS) that was followed byT_1, T_3-T_5 and T_7-T_{15}. The lowest dry matter was found at T_{16} (USG placed at 15 cm depth at 30 DAS) and was similar with T_1-T_5 and T_7-T_{15}.

At harvest T_7 (USG placed at 5 cm depth at 20 DAS) showed higher (12.94 g) dry matter production which was statistically at per with T_1 (PU broadcasted (conventional method)), T_2 (PU given in the side furrows), T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_9 (USG placed at 10 cm depth as basal), T_{11} (USG placed at 10 cm depth at 20 DAS), T_{13} (USG placed at 15 cm depth as basal), T_{14} (USG placed at 15 cm depth at 10 DAS) and T_{15} (USG placed at 15 cm depth at 20 DAS). And the lowest was found at T_8 (USG placed at 5 cm depth at 30 DAS) that was followed by T_4-T_6 and T_8-$T_{16.}$

USG (5 cm depth at 20 DAS) gave 25.27% higher above ground dry matter production over PU (conventional method). Figure 3 showed that the plants those received N in the form of USG had always maintained higher dry matter compared to PU. It might be due to continuous availability of N from the deep placed USG that released N slowly and it enhanced growth to crop more than that of PU.

Similar results were also obtained by Das (1989) and Rao *et al.* (1986) and they reported that USG was the most effective in increasing TDM than split application of urea. Deep placement of USG in the root zone was most effective in increasing dry matter production than PU (Rambabu *et al.*, 1983).

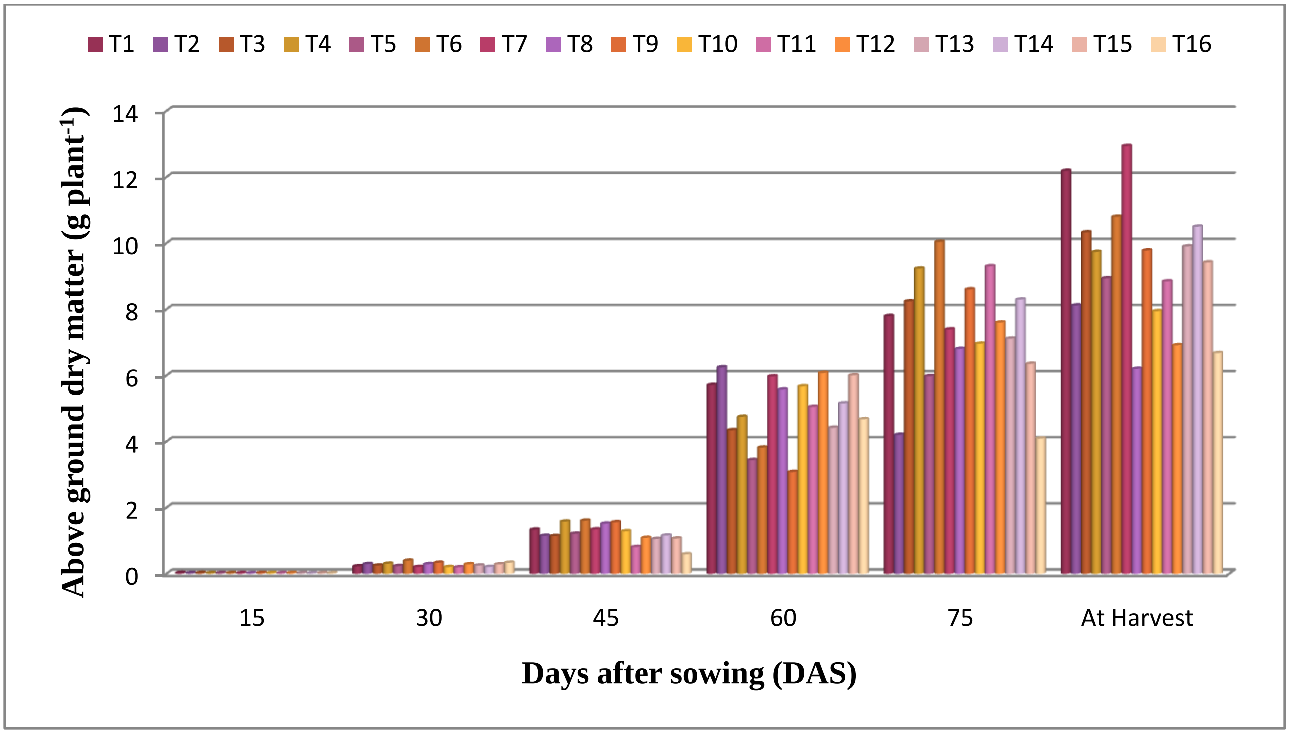


Figure 4. Total dry matter of mustard plant at different growth stages as affected by different nitrogen application methods ($LSD_{0.05}$ = 0.05, 0.15, 0.70, 3.64, 5.12 and 4.11 at 15, 30, 45, 60, 75 DAS and at harvest respectively)

T_1= PU broadcasted (conventional method)
T_2= PU given in the side furrows
T_3= PU given between two rows
T_4= PU and seed given in the same furrows
T_5= USG placed at 5 cm depth as basal
T_6=USG placed at 5 cm depth at 10 DAS
T_7= USG placed at 5 cm depth at 20 DAS
T_8= USG placed at 5 cm depth at 30 DAS
T_9= USG placed at 10 cm depth as basal
T_{10}= USG placed at 10 cm depth at 10 DAS
T_{11}= USG placed at 10 cm depth at 20 DAS
T_{12}= USG placed at 10 cm depth at 30 DAS
T_{13}= USG placed at 15 cm depth as basal
T_{14}= USG placed at 15 cm depth at 10 DAS
T_{15}= USG placed at 15 cm depth at 20 DAS
T_{16}= USG placed at 15 cm depth at 30 DAS

4.2 Effect of different application methods of nitrogen on yield attributes

4.2.1 Siliquae plant^{-1} (no.)

Siliquae plant^{-1} was affected significantly by nitrogen management methods (Table-1 and Appendix-IX). The maximum number (58.60) of siliquae plant^{-1} was produced in T_7 (USG at 5 cm depth at 20 DAS) which was statistically similar with T_1 (PU broadcasted (conventional method)), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS) and T_{14} (USG placed at 15 cm depth at 10 DAS). This might be due to the fact that USG receiving plants got continuous supply of N and plants could better utilize it thus yield parameters could response positively. The lowest (27.92) number of siliquae was found at T_{16} (USG at 15 cm depth at 30 DAS) that was statistically similar with T_2, T_3, T_6-T_8, T_{11}-T_{15}. Results revealed that USG given plot gave 32.73% higher siliquae plant^{-1} than the conventional (broadcasting) use of PU.

The result was supported by Jee and Mahapatra (1989) they reported that panicles m^{-2} was significantly higher @ 90 kg ha^{-1} as deep placement of urea super granules (USG) than split application of urea. BARI (2008) conducted several experiments on various crops as brinjal, potato, hybrid maize etc. and reported that these crops gave higher fruit plant^{-1}, tuber haulm^{-1}, and cob plant^{-1}, respectively with USG application.

4.2.2 Seeds siliqua^{-1} (no.)

Nitrogen management did not significantly influence the number of seeds siliqua^{-1}. However, result (Table 1 and Appendix-IX) showed that numerically the highest (32.00) seeds siliqua^{-1} was produced at T_7 (USG placed at 5 cm depth at 20 DAS) and lowest (26.33) was at T_8 (USG placed at 5 cm depth at 30 DAS). USG treated plot gave 1.04% higher yield over PU.

Similar result was observed by Masum (2008) and found that higher number of filled grains panicle^{-1} was obtained with USG (105.91) than urea (99.73) in rice cultivation. Rama *et al.* (1989) reported higher filled grains panicle^{-1} with 40, 80 or 120 kg N ha^{-1} applied as USG over split application of urea.

4.2.3 1000-seed weight (g)

The effect of application method of PU and USG was not significant in respect of 1000-seed weight. Numerically the maximum (3.56 g) 1000-seed weight (Table 1 and Appendix-IX) was recorded in T_7 (USG placed at 5 cm depth at 20 DAS) and minimum in T_{14} (USG placed at 15 cm depth at 10 DAS).

The findings also accord with the report by Yoshida (1981) and stated that the 1000-seed weight is more or less a stable genetic character and N management strategy could not increase the grain weight in this case. On the other hand, Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea super granules (USG) and broadcasting prilled urea (PU) as sources of N in T. *aman* rice and observed that USG produced the highest 1000-grain weight.

Table 1 Effect of nitrogen application methods on different yield attributes of mustard

Treatment	**Siliquae Plant^{-1} (No.)**	**Seeds Siliqua^{-1} (No.)**	**1000-seed weight (g)**
T_1	44.15	31.67	3.30
T_2	33.84	31.33	3.47
T_3	41.75	31.00	3.27
T_4	42.26	31.67	3.10
T_5	42.87	31.00	3.27
T_6	40.40	30.67	3.30
T_7	58.60	32.00	3.56
T_8	39.67	26.33	3.24
T_9	43.92	31.67	3.15
T_{10}	43.53	29.67	3.46
T_{11}	31.67	31.67	2.97
T_{12}	29.67	31.00	3.05
T_{13}	41.27	31.00	3.26
T_{14}	43.12	30.67	2.91
T_{15}	39.87	31.33	3.33
T_{16}	27.92	30.67	3.43
LSD (0.05)	**14.41**	**2.63**	**0.59**
CV%	**21.45**	**5.12**	**10.87**

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

Seed yield is a combined output of various yield components such as siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and 1000 seed weight. Seed yield affected significantly due to application methods of N-fertilizer (Figure 5 and Appendix- IX). Higher (3.59 t ha^{-1}) seed yield in T_7 (USG placed at 5 cm depth at 20 DAS) indicated it's superiority over split application of PU (2.58 t ha^{-1}). The maximum seed yield in T_1 (PU broadcasted (conventional method)) was statistically similar with T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_5 (USG placed at 5 cm depth as basal), T_9 (USG placed at 10 cm depth as basal), T_{10} (USG placed at 10 cm depth at 10 DAS) and T_{13} (USG placed at 15 cm depth as basal). The minimum seed yield (1.52 t ha^{-1}) was observed in T_{16} (USG placed at 15 cm depth at 30 DAS) that was followed by T_1-T_6 and T_8-T_{15}.

Placement of USG at 5 cm depth at 20 DAS (T_7) produced the highest siliquae $plant^{-1,}$ seeds $siliqua^{-1}$ and 1000 seed weight which ultimately gave 39.14% higher seed yield than PU broadcasted (T_1). This higher yield might be attributed due to the fact that the plant had nourished with adequate nitrogen fertilizer as it required during growth period thus ultimately gave higher yield components for higher seed yield. This result is in agreement with BRRI (2000) that USG gave 18% yield increase over the recommended prilled urea. Similar results were also reported by Mishra *et al.* (2000) and Raju *et al.* (1987) who observed that among all the forms of N, USG recorded the highest grain yield and proved significantly superior to other sources. Singh and Singh (1992) and Dwivedi and Bajpai (1995) found that application of nitrogen as USG gave higher yield than other sources of nitrogen.

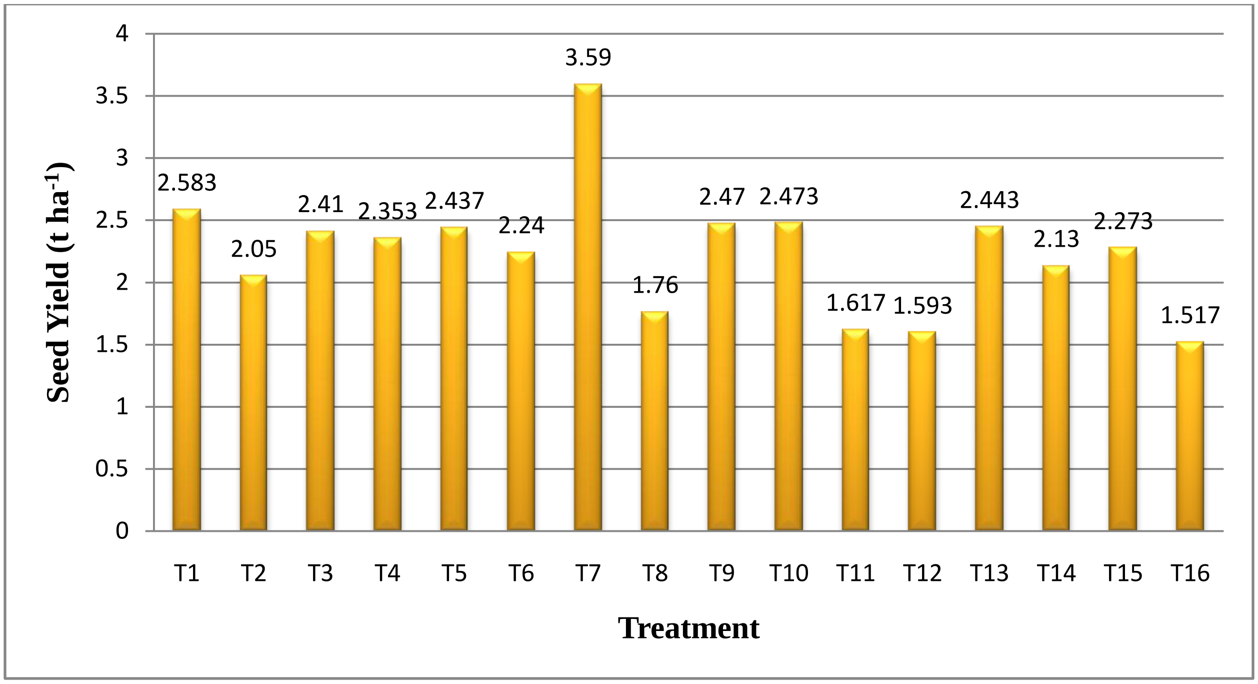


Figure 5. Effect of nitrogen application methods on the seed yield of mustard (LSD $_{0.05}$= 1.095)

T_1= PU broadcasted (conventional method)
T_2= PU given in the side furrows
T_3= PU given between two rows
T_4= PU and seed given in the same furrows
T_5= USG placed at 5 cm depth as basal
T_6=USG placed at 5 cm depth at 10 DAS
T_7= USG placed at 5 cm depth at 20 DAS
T_8= USG placed at 5 cm depth at 30 DAS
T_9= USG placed at 10 cm depth as basal
T_{10}= USG placed at 10 cm depth at 10 DAS
T_{11}= USG placed at 10 cm depth at 20 DAS
T_{12}= USG placed at 10 cm depth at 30 DAS
T_{13}= USG placed at 15 cm depth as basal
T_{14}= USG placed at 15 cm depth at 10 DAS
T_{15}= USG placed at 15 cm depth at 20 DAS
T_{16}= USG placed at 15 cm depth at 30 DAS

4.2.5 Stover yield (t ha $^{-1}$)

The nitrogen application favorably influenced the stover yield and the differences among the treatments were significant (Table 2 and Appendix- X). They highest stover yield (4.07 t ha^{-1}) was found at T_1 (PU broadcasted (conventional method)) and was at par with T_3 (PU given between two rows), T_4 (PU and seed given in the same furrows), T_6 (USG placed at 5 cm depth at 10 DAS) and T_{13} (USG placed at 15 cm depth as basal). The lowest (2.61 t ha^{-1}) stover yield was found at T_8 (USG placed at 5 cm depth at 30 DAS) that was statistically similar with T_2, T_4-T_7 and T_9-T_{16}.

From the study, it was observed that PU produced dry matter that partitioned more to source (stover) rather than sink (seed). As a result, seed yield was lower in PU applied plot than USG.

These findings were an agreement with that of Singh and Prasad (2003), Singh *et al.* (2002) and Meena *et al.* (2002) who observed higher stover yield of mustard with successive increase of the nitrogen level.

4.2.6 Biological yield (t ha $^{-1}$)

It was evident from the results (Table 2 and Appendix- X) that biological yield was significantly affected by the different methods of N fertilizer. The maximum biological yield (6.78 t ha^{-1}) was found from T_7 (USG placed at 5 cm depth at 20 DAS) that was statistically similar with T_1-T_6, T_9, T_{10} and T_{13}-T_{15}. On the other hand, the lowest biological yield (4.26 t ha^{-1}) was obtained from T_{12} (USG placed at 10 cm depth at 30 DAS) that was followed by T_2, T_4-T_6, T_8-T_{11} and T_{13}-T_{16}.

The biological yield increased with the increasing rate of nitrogen level stated by Shrirame *et al.* (2000).

4.2.7 Harvest index (%)

Harvest index is the ratio of economic yield and biological yield. Harvest index was significantly affected due to nitrogen sources (Table 2 and Appendix- X). Urea super granules (T_7 = USG placed at 5 cm depth at 20 DAS) showed its superiority by showing higher harvest index (52.62 %) than PU and that was statistically similar with T_4-T_6, T_8-T_{10} and T_{13}-T_{15}. The lowest harvest index (30.62 %) was found at T_{11} (USG at 10 cm. depth at 20 DAS) that was statistically similar with rest of the treatments except T_7.

It is again ascertained that higher partitioned of dry matter to sink might be happened with the use of USG that PU.

Table 2 Effect of nitrogen application methods on stover yield, biological yield and harvest index of mustard

Treatment	Stover yield (t ha $^{-1}$)	Biological yield (t ha $^{-1}$)	Harvest index (%)
T_1	4.07	6.65	37.04
T_2	3.24	5.29	36.10
T_3	3.74	6.15	36.81
T_4	3.36	5.71	38.26
T_5	3.19	5.63	42.30
T_6	3.29	5.53	38.46
T_7	3.19	6.78	52.62
T_8	2.61	4.37	38.49
T_9	3.24	5.71	43.29
T_{10}	2.97	5.44	44.58
T_{11}	2.97	4.58	30.62
T_{12}	2.66	4.26	33.22
T_{13}	3.30	5.75	39.29
T_{14}	2.98	5.11	39.67
T_{15}	2.80	5.07	44.28
T_{16}	2.85	4.37	32.85
LSD (0.05)	**0.7075**	**1.488**	**13.24**
CV%	**13.43**	**16.52**	**20.23**

Chapter 5

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was conducted at the Agronomy Field laboratory of the Sher-e-Bangla Agricultural University, Dhaka during the period from November'09 to February'10, situated under the Modhupur Tract (AEZ-28). The research work was done to investigate the influence of application method of nitrogen application on the growth and yield of mustard. The experimental treatments included two forms of urea *viz.* prilled urea (PU) and urea super granules (USG) at the rate of 300 kg ha^{-1} and 142.86 kg ha^{-1} (2.7 g per USG), respectively. The treatments were i.e., T_1= Prilled Urea (PU) broadcasted (conventional method), T_2= PU given in the side furrows, T_3= PU given between two rows, T_4=PU and seed given in the same furrows, T_5= Urea Super Granules (USG) placed at 5 cm depth as basal, T_6= USG placed at 5 cm depth at 10 days after sowing (DAS), T_7= USG placed at 5 cm depth at 20 DAS, T_8= USG placed at 5 cm depth at 30 DAS, T_9= USG placed at 10 cm depth as basal, T_{10}= USG placed at 10 cm depth at 10 DAS, T_{11}= USG placed at 10 cm depth at 20 DAS, T_{12}= USG placed at 10 cm depth at 30 DAS, T_{13}= USG placed at 15 cm depth as basal, T_{14}= USG placed at 15 cm depth at 10 DAS, T_{15}= USG placed at 15 cm depth at 20 DAS and T_{16}= USG placed at 15 cm depth at 30 DAS. The experiment was laid out in a randomized complete block design (RCBD) design with three replications. There were 16 treatments within which first 4 plots were assigned for PU and rest 12 was for USG. Total number of unit plot was 48 and size of unit plot was 4.25×2.5 m^2. The distance maintained between 2 unit plots was 0.75 m and that between replications was 1.5 m.

All the unit plots were equally provided with P_2O_5 in the form of triple super phosphate (TSP), K_2O in the form of muriate of potash (MP) and gypsum at the rate of 180, 100 and 180 kg ha^{-1}, respectively as basal dose. Prilled urea (PU) was applied two equal splits, the first one-half of urea was applied as basal and second one-half was applied at 30 DAS. On the other hand, USG (2.7 g) was placed in 5, 10 and 15 cm depth of soil and each at basal, 10, 20 and 30 DAS in separate plots. Intercultural operations such as thinning, weeding, irrigation, drainage and pest management were done as and when necessary. Ten plants plot^{-1} excluding the border ones were selected at random and uprooted prior to harvest for recording data on crop parameter under study for each sampling dates. The crop was harvested when 90% of the plants become golden yellow color and was done on 19 February 2010. The threshing was done manually. The seeds were cleaned and sun dried to moisture content of 10%. Stover was also sun dried properly. The data on crop growth characters like plant height (at 15, 30, 45, 60, 75 DAS and at harvest), branches plant^{-1} (at 60, 75 DAS and at harvest), leaf area index (at 15, 30, 45 and 60 DAS) and above ground dry mater (at 15, 30, 45, 60, 75 DAS and at harvest) were recorded. On the other hand yield components like siliquae plant^{-1} (no.), seeds siliqua^{-1} (no.), 1000-seed weight (g), seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were recorded after harvest. Data was analyzed by following the ANOVA technique using statistical program MSTAT-C and mean differences was adjudged with LSD at 5% level of significance.

Nitrogen application methods significantly influenced all growth characters but at 15 and 60 DAS plant height, at 75 DAS branches plant^{-1} and at 15 and 60 DAS of above ground dry matter production remained unaffected. Prilled urea (300 kg ha^{-1}) produced the tallest plant height 7.35, 74.00, 77.44 and 86.80 cm, respectively at 15, 30, 60, 75 DAS and at harvest. On the other hand, USG (142.86 kg ha^{-1}) showed peak plant height (61.11 cm) at 45 DAS. Branches plant^{-1} (No.) at 60 DAS was highest (5.55) with PU treated plot. But 75 DAS (5.33) and at harvest (6.86) showed maximum branches plant^{-1} from USG treated plot. Also USG gave the highest LAI (1.08, 1.99, 2.78 and 3.55 at 15, 30, 45 and 60 DAS respectively) at all the growth stages. PU produced maximum 0.02g and 6.24 g above ground dry matter at 15 and 60 DAS respectively. Dry matter was found superior with USG (5 cm depth) treated plant as 0.39, 1.60, 11.94 and 12.94 g at 30, 45, 75 DAS and at harvest, respectively.

Results showed that different managements of nitrogen had significant effect on all the yield parameters except 1000-grain weight. Treatment T_7 (USG given in 5 cm. depth at 20 DAS) gave the maximum number of siliquae plant^{-1} (58.6), seeds siliqua^{-1} (32.0) and 1000-seed weight (3.56 g). As a result, USG placed in 5 cm depth at 20 DAS gave the maximum seed yield (3.59 t ha^{-1}), biological yield (6.78 t ha^{-1}) and harvest index (52.62%). In contrast, the conventional (broadcasting) use of prilled urea gave siliquae plant^{-1} (44.15), seeds siliqua^{-1} (31.67) and 1000-seed weight (3.30 g) with seed yield (2.58 t ha^{-1}), biological yield (6.66 t ha^{-1}) and harvest index (37.04%) those were comparatively lower.

On the other hand, stover yield was maximum (4.07 t ha^{-1}) with PU (T_1= PU broadcasted (conventional method)) whereas lowest (2.61 t ha^{-1}) found at USG given plot (T_8= USG placed at 5 cm depth at 30 DAS).

From the above discussion, the following conclusions may be drawn

- ❖ USG placed in 5 cm depth at 20 DAS gave higher seed yield of mustard over Prilled urea.
- ❖ 52.38% less use of urea as urea super granules (USG) over prilled urea (PU) which gave 39.14% of more seed yield than PU.

To arrive at sound conclusion, it is important to do further experimentation with the use of urea super granules (USG) on mustard in the potential production areas of Bangladesh.

REFERENCES

REFERENCES

Ahmed, M. H., Islam, M. A., Kader, M. A. and Anwar, M. P. (2000). Evaluation of urea supergranules as a source of nitrogen in T. *aman* rice. *Pakistan J. Biol. Sci.* **2**(5): 735-737.

Alam, B. M. R. (2002). Effect of different level of urea superranule on growth and yield of three varieties of Boro rice. MS thesis. Department of Agronomy, Banladesh Agricultural University, Mymensinh.

Ali, M. A. (2005). Productivity and resource use efficiency of rice as affected by crop establishment and N management. PhD Dissertation, UPLV, Philippines. p. 182.

Ameta, G. S. and Singh. H. G. (1990). Comparative efficiency of neem cake coated prilled urea and splitting-N application in rice production. *Intl. Trop. Agric.* **8**(3): 189-192.

Anonymous. (2003). Application of Urea Super Granules (USG) in vegetable crops. A Profitable Technology. Bangladesh Agril. Res. Institute and SFFP Dept. Agril. Ext. pp. 1-10.

Apparao, G. (1983). Efficiency of urea super granules. *Seed and Farms.* **9**(6): 50-51. [*Rice Abst. (1985).* ***8****(4): 56*]

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

BARI (Bangladesh Agricultural Research Institute). (1999). Annual Report for 1997-1998. Gazipur-1701, Bangladesh. p. 138.

BARI (Bangladesh Agricultural Research Institute). (2008). Annual Report for 2007-08. Gazipur-1701, Bangladesh. pp. 1-39, 195, 385.

BARI (Bangladesh Agricultural Research Institute). (2010). Annual Report for 2010-11. Gazipur-1701, Bangladesh.

BBS (Bangladesh Bureau of Statistics). (1999). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2002). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2005). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2007). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). (2010). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka.

Bharat, S. and Srivastava, O.P. (1989). Use of urea super granules for increasing nitrogen use efficiency in rice. *Farm Sci. J.* **4**(1-2): 75-85.

BRRI (Bangladesh Rice Research Institute). (2000). Annual Report for 1999-2000. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. p. 138.

Cassman, K., Dobermann, A. and Watters, D. (2002). Agroecosystems, nitrogen use efficiency and nitrogen management, *Ambio.* **31**(2): 132-140.

Chalam, A. M., Chakravorti, S. P. and Mohanty, S. K. (1989). Comparative efficiency of urea supergranules and prilled urea for lowland rice (*Oryza sativa* L.) using N. *Indian J. Agric. Sci.* **59**(6): 400-401.

Chauhan, H. S. and Mishra, B. (1989). Fertilizer use efficiency of amended urea materials in flooded rice. *J. Agric. Sci.* **112**(2): 277-821.

Craswell, E. T. and De Datta, S. K. (1980). Recent developments in research on nitrogen fertilizers for rice. *Indian J. Agron.* **31**(4): 387-389.

Das, D. K. (1989). Efficiency of different urea materials for rainy season rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59**(8): 534-536.

Das, S. and Singh, T. A. (1994). Nitrogen use efficiency by rice flood water parameters as affected by fertilizer placement techniques. *J. Indian Soc. Soil Sci.* **42**(1): 46-50.

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

De Datta, S. and Buresh, R. (1989). Integrated nitrogen management in irrigated rice. *Advance in soil science.* **10**:143-169.

Dinnes, D.L., Karlen, D.L., Jayne, D.B., Kasper, T.C., Hatfield, J.L., Colvin, T.S. and Cambardella C.A. (2002). Nitrogen managent strategies to reduce nitrate leaching in tile-drained Midwestern soils. *Agron. J.* **94**: 153-171.

Dwivedi, R.K., and Bajpai. R.P. (1995). Effect of different sources of urea and nitrogen levels on lowland rice. *J. Agril. Res.* **7**(2): 161-162.

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

Galloway, J. N., Aber, J., Erisman, J. W., Seitzinger, S. P. Howarth, R., Cowling, E.B. and Cosby, B. J. (2003). *The nitrogen cascade Biol. Science.* **53**(4):341-356.

Gardner, P.P., Pearce, R.B. and MistecheU, R.L. (1985). Physiology of Crop Plants. Iowa State Univ. Press, Iowa. p. 66.

Hasan, M. S., Hossain, S. M. A., Salim, M., Anwar, M. P. and Azad, A. K. M. (2002). Response of Hybrid and Inbred rice Varieties to the Application Methods of Urea supergranules and Prilled Urea. *Pakistan J. Bio. Sci.* **5** (7): 746-748.

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

Ibrahim, A.F., Abusteit, E.O. and Et-Met-Wally, Et. M. A. (1989). Response of rapeseed (*Brassica napus* L.) growth, yield, oil content and its fatty acids to nitrogen rate and application times. *J. Agron. Crop Sci.* **62**: 107-112.

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

Jaiswal, V. P. and Singh, G. R. (2001). Performance of urea super granules and prilled urea under different planting method in irrigated rice *(Oryza sativa). Indian J. Agric. Sci.* **71**(3): 187-189.

Jee, R.C. and Mahapatra, A.K.I. (1989). Effect of time application of some slow release N-fertilizers on rice. *Indian J. Agron,* **34**(4): 435-436.

Johnkutty, I. And Mathew, P. B. (1992). Large granule urea, an efficient and economic source of N for wetland rice. *Intl. Rice Res. News.* **17**(3): 16- 17.

Kamal, J., Tomy, P.J. and Rajappan, N. (1991). Effect of sources and levels of nitrogen use efficiency of wetland rice. *Indian J. Agron.* **36**(1): 40-43.

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

Mae, T. (1997). Physiological nitrogen efficiency in rice: nitrogen utilization, photosynthesis and yield potential. **In**: Plant Nutrition for Sustainable Food Production and Environment. T. Ando, K. Fujita, T. Mae, H. Matsumoto, S. Mori and J. Skiya, (Ed.). Kluwer Academic Publishers, Doordrecht, Netherlands. pp. 51-60.

Masum, S. M. (2008). Growth and yield of T. Aman rice varieties as affected by seedling number hill^{-1} and urea super granules. M. S. Thesis, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

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

Miah, M.N.H., Mian, Talukder, S., Sanker, M.A.R. and Ansary, T.H. (2004). Effect of number of seedling hill^{-1} and urea super granules on growth and yield of rice cv. BINA dhan-4. *J. Biol. Sci.* **4**(2): 122-129.

Mirzeo, W.A. and Reddy, S.N. (1989). Performance of modified urea materials at graded levels of nitrogen under experimental and farmer's management conditions in low land rice *(Oryza sativa). Indian J. Agril. Sci.* **59**(3): 154-160.

Mishra, B. K., Mishra, S., Dash, A. k. and Jena, D. (2000). Effect of time for urea super granules (USG) placement on low land rice. *Ann. Agril. Res.* **20**(4): 4, 443-447.

Mishra, B.K., Das, A.K., Dash, A.K., Jena, D. and Swain, S.K. (1999). Evaluation of placement methods for urea super granules in wet land rice *(Oryza sativa)* soil. *Indian J. Agron.* **44**(4): 710-716.

Mohanty, S. K., Singh, U., Balasumbramanian, V., Jha, K.P., Ladha, J.K. and Denning, G.L. (1999). Nitrogen deep placement technologies for productivity, profitability and environmental quality of rainfed low land rice systems: nutrients. *Nutrient Cycling in Agro-ecosystems.* **53**(l):43-57.

Mohanty, S.K., Chakravirti, S.P. and Bhadrachlam, A. (1989). Nitrogen Balance studies in rice using N labeled urea and urea super granules. *Indian J. Aric.Sci.* **113**(1): 119-121.

Naseem, S.B., Mollah, M.I.U. and Ali, M.H. (1995). Yield response of upland rice to varying levels of weeding and nitrogen. *Bangladesh J. Res.* **301**(2-3):65-71.

Nayak, P. L., Mandal, S. S., Das, M. and Patra, H. P. (1986). Effect of granulated, coated and pilled urea on the growth and yield of minted low land rice. *Environ. Ecol.* **4**(4): 602-604.

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

Patel, M. R. and Desai, N. D. (1987). Sources and methods of N application for irrigated wetland rice. *Intl. Rice Res. News*. **12**(2): 43.

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

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

Quayum A. and Prasad, K. (1994). Performance of modified urea materials in rainfed low land rice *(Oryza sativa* L.). *J. Res. Birsa Agric. Univ.* **6**(2): 131-133. [*Rice Abst. 1996.* ***19****(2): 112*].

Rahman, M.A. (2003). Effect of levels of urea super granules and depth of placement on the growth and yield of transplanted *aman* rice. M.S. (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh.

Raju, R. A., Mustafa Hossain, and Nageswarip. R. M. (1987). Relative efficiency of modified urea materials for low land rice. *Indian J. Agron.* **32**(4): 460-462.

Rama, S., Reddy, G. and Reddy, K. (1989). Effect of levels and sources of nitrogen on rice. *Indian J. Agron.* **34**(3): 364-366.

Rambabu, P., Pillai, K. G. and Reddy, S. N. (1983). Effect of modified ureas materials and their methods of application on dry matter production, grain yield and nitrogen uptake in rice. *Oryza*. **20**: 86-90.

Rao, C.M., Ramaish, N. V., Reddy, S.N. and Reddy, G. V. (1986). Effect of urea and urea supergranules on dry matter accumulation yield and nutrient uptake in rice *(Oryza sativa). J. Res.* **14**: 1-3.

Reddy, G. R. S., Reddy. G. B., Ramatah, N. V. and Reidy, G. V. (1986). Effect of different levels of nitrogen and forms of urea on growth and yield of wetland rice. *Indian J. Agron.* **31**(2): 195-197.

Rekhi, R. S., Bajwa, M. S. and Sattar, T. L. (1989). Efficiency of PU and USG in rapidly percolating soil. *Intl. Rice Res. News*. **14**(2): 28-29.

Roy, B. C., Mazid, M. A. and Siddique, S. B. (1991). Efficiency of different forms and application methods of N fertilizer on rainfed low land rice. *Bangladesh Rice J.* **2**(1&2): 75-78.

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

Savant, N. K., Dhane, S. S. and Talashilkar, S. C. 1991. Fertilizer News. International Fertilizer Development Centre, USA. Pert. News. 36(3): 19-25.

Sen. A., Gulatin, J. M. L. and Mohanty, J. K. (1985). Effects of root zone placement of nitrogen as urea supergranules on the yield performance of wetland rice. *Oryza sp.* **22**(1): 40-44. [*Field Crop Abst. (1987)* ***40****(2): 121*].

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

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

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

Shrirame, M.D. Rajgire, H.J. and Rajgire, A.M. (2000). Effect of spacing and seedling number hill^{-1} on growth attributes and yield of rice hybrids under lowland condition. *Indian J. Soil Crops.* **10**(1): 109-113.

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

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

Singh, G. and Singh, O. P. (1993). Effect of method of seedling and level of ntrogen on yield an-1 yield attributes of rice *(Oryza sativa* L.) under flood affected condition. *Indian J. Agron.* **38(4):** 551-554.

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

Singh, B.K. and Singh, R.P. (1986). Effect of modified urea materials on rainfed low land and transplanted rice and their residual effect on succeeding wheat crop. *Indian J. Agron.* **31**(2): 198-200.

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

Singh, K. and Singh, K. (1992). Nitrogen economy through modified forms of urea application in rice. *Crop Res. Hisar*. **5**(3): 445-450.

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

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

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

Singh. G. R. and Singh, T. A. (1988). Leaching losses and use efficiency of nitrogen in rice fertilized with urea super granules. *Indian J. Soil Sci.* **32**(2): 274-279. [*Rice Abst. (1989).* ***12****(2): 68*]

Sinha, S., Nayak, R. L. and Mitra, B. (2003). Effect of different levels of nitrogen on the growth of rapeseed under irrigated and rainfed conditions. *Env. Ecol.* **21**(4): 741-743. State Univ. Press, Iowa. p. 66.

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

Surendra, S., I. Prasad and Sharma, S. N. (1995). Effects of blue green algae, nitrogen levels and modified urea materials on yield attributes and yield .of vet land rice *(Oryza saliva). Indian J. Agron.* **40**(4): 594-597.

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

Thakur, R. B. (1991). Relative efficiency of prilled urea and modified urea fertilizer on rainfed low land rice. *Indian J. Agron.* **36**(1): 87-90.

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

Vijaya, D. and Subbaiah, S.V. (1997). Effects of method of application of granules forms of fertilizers on growth, nutrient uptake and yield of paddy. *Ann. Agril. Res.* **18** (3): 361-364.

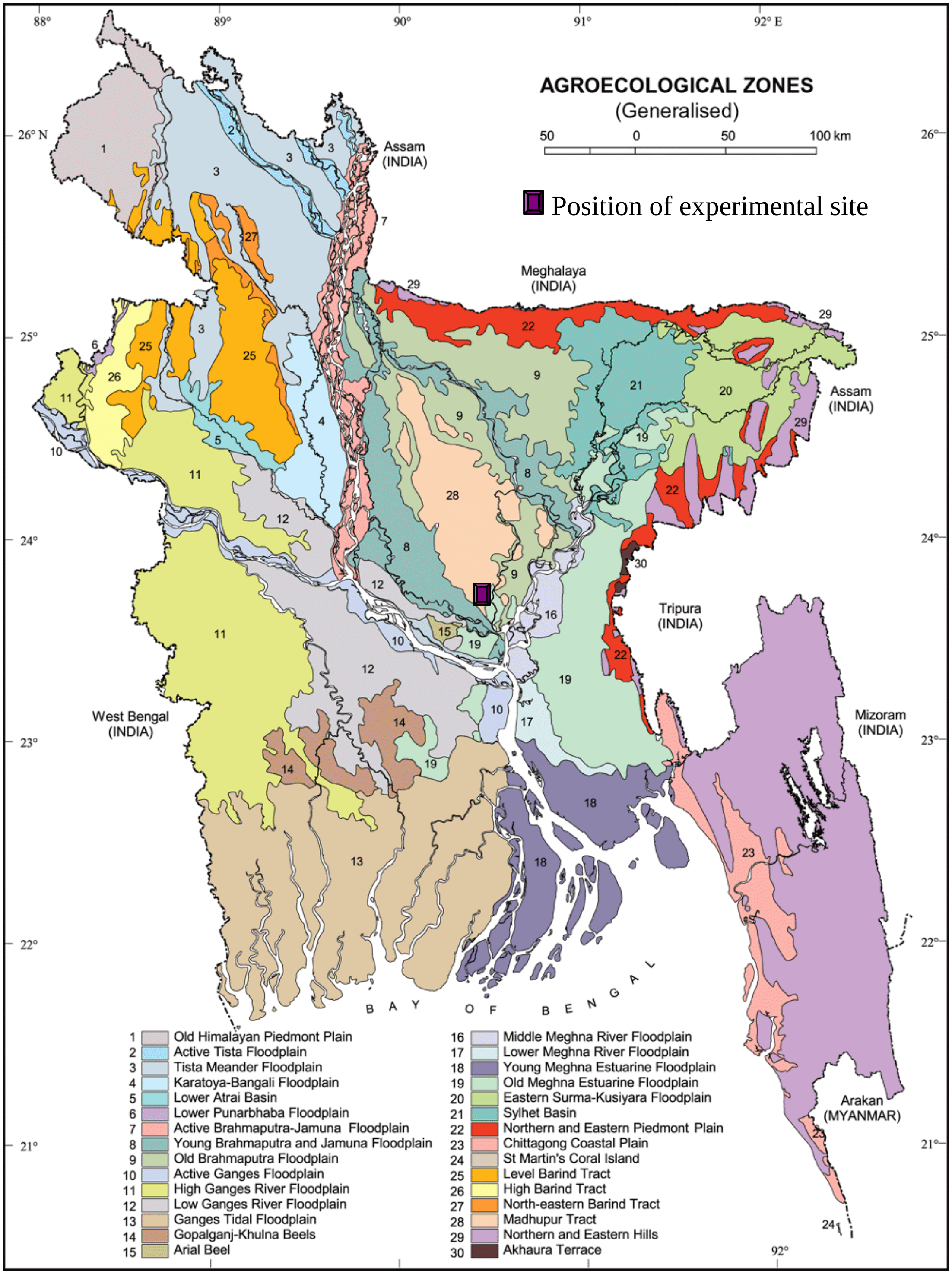
Yoshida, S. (1981). Physiological analysis of rice yield. **In**: Fundamentals of Rice Crop Science. IRRI, Los Banos, Philippines. pp. 1-41, 269.

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

APPENDICES

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly average air temperature, relative humidity, total rainfall and sun shine hours of the experimental site during November'09- February'10

Year	Month	Air Temperature (^{0}C)			Relative Humidity (%)	Total Rainfall (mm)	Sun Shine (hr)
		Max.	Min.	Mean			
2009	Nov.	29.6	19.0	24.3	77.0	34.4	5.7
	Dec.	26.4	14.1	20.25	69.0	12.8	5.5
2010	Jan.	25.4	12.7	19.05	68.0	7.7	5.6
	Feb.	28.1	15.5	21.8	68.0	28.9	5.5

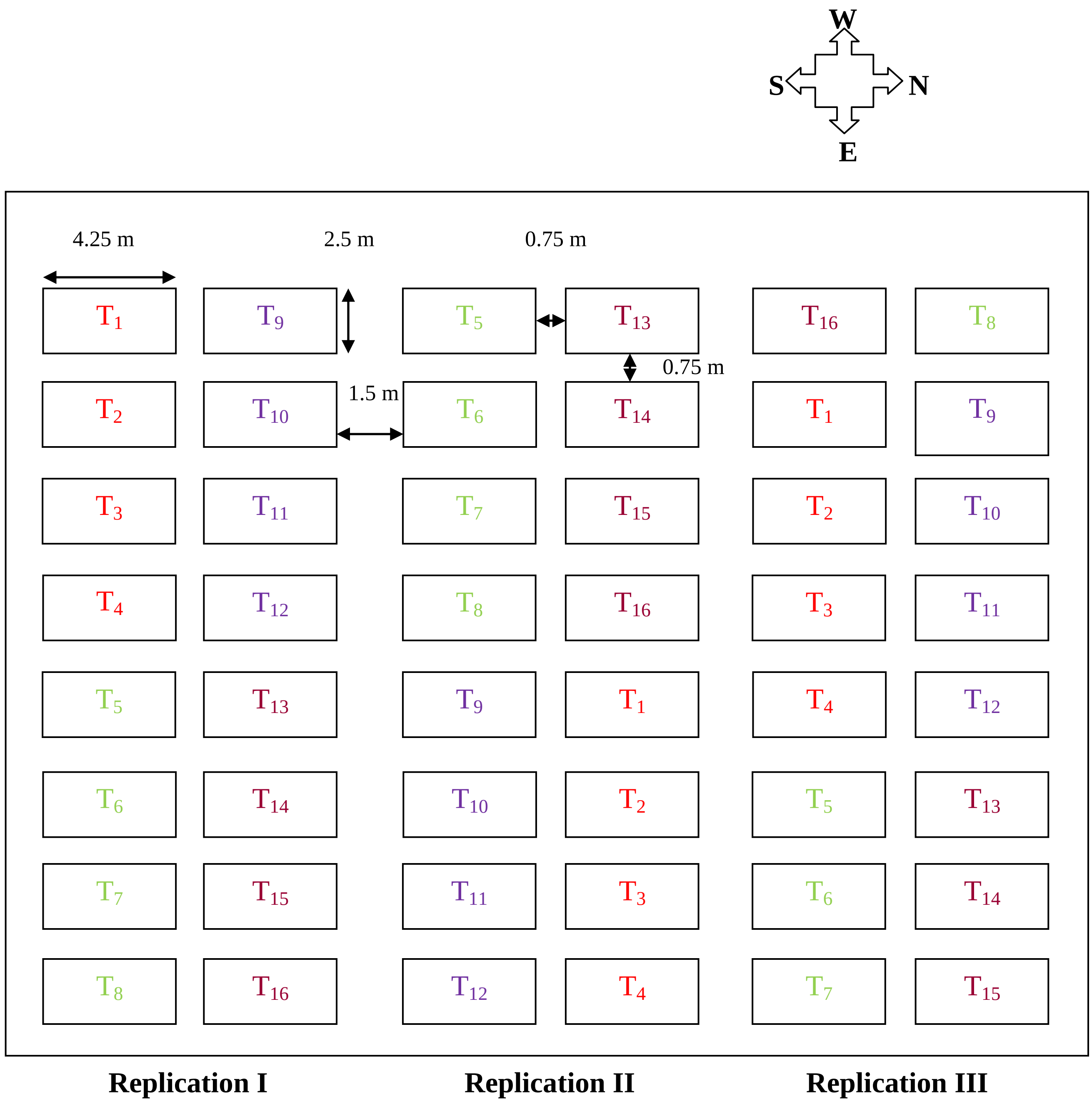
Source: Bangladesh Meteorological Department (Climate division), Agargaon Dhaka-1207

Appendix III. Physiochemical characteristics of the initial soil

Characteristics	Value
Partical size analysis	
% Sand	25.68
% Silt	53.85
% Clay	20.47
Textural class	silty loam
pH	7.1
Organic carbon (%)	0.31
Organic matter (%)	0.54
Total N (%)	0.027
Available P (µg/ g soil)	23.64
Exchangeable K (me/ 100 g soil)	0.60
Available S (µg/ g soil)	28.43
Available B (µg/ g soil)	0.05
Available Zn (µg/ g soil)	2.31

Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix IV. Layout of the experimental field



Appendix V. Means square values for plant height (cm) of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)					
		15	30	45	60	75	At harvest
Replication	2	10.93	40.55	749.44	1485.41	736.36	1723.45
Treatment	15	0.84*	6.77*	65.24*	30.35^{ns}	52.42*	68.12*
Error	30	0.77	3.19	49.59	31.16	43.23	27.84
CV (%)		13.77	11.49	13.46	8.16	9.36	6.8

*Significant at 5% level

^{ns} Non-Significant

Appendix VI. Means square values for branches plant^{-1} (No.) of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)		
		60	75	At harvest
Replication	2	16.64	0.51	12.09
Treatment	15	3.21*	0.97^{ns}	1.51*
Error	30	1.90	0.99	0.83
CV (%)		35.14	20.95	15.61

*Significant at 5% level

^{ns} Non-Significant

Appendix VII. Means square values for leaf area index (LAI) of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)			
		15	30	45	60
Replication	2	0.64	3.51	26.16	67.46
Treatment	15	0.23*	0.31*	0.48*	0.66*
Error	30	0.07	0.06	0.17	0.41
CV (%)		23.45	21.13	26.87	25.66

*Significant at 5% level

Appendix VIII. Means square values for above ground dry matter (g) of mustard at different days after sowing (DAS)

Sources of variation	Degrees of Freedom	Means square values at different days after sowing (DAS)					
		15	30	45	60	75	At harvest
Replication	2	0.00	0.01	2.03	41.18	25.89	224.18
Treatment	15	0.00	0.01*	0.23*	2.89^{ns}	11.09*	10.59*
Error	30	0.00	0.01	0.17	4.76	9.41	6.09
CV (%)		30.63	32.59	34.47	43.65	40.93	26.45

*Significant at 5% level

^{ns} Non-Significant

Appendix IX. Means square values for Siliquae Plant^{-1} (No.), Seeds Siliqua^{-1} (No.), 1000-seed weight (g) and seed yield (t ha^{-1}) of mustard

Sources of variation	Degrees of Freedom	Means square values			
		Siliquae Plant^{-1} (No.)	Seeds Siliqua^{-1} (No.)	1000-seed weight (g)	Seed yield (t ha^{-1})
Replication	2	2497.95	17.33	1.99	19.99
Treatment	15	155.58*	5.28*	0.09^{ns}	0.76*
Error	30	74.68	2.48	0.13	0.43
CV (%)		21.45	5.12	10.87	29.23%

*Significant at 5% level

^{ns} Non-Significant

Appendix X. Means square values for Stover Yield (t ha $^{-1}$), Biological Yield (t ha^{1}) and Harvest Index (%) of mustard

Sources of variation	Degrees of Freedom	Means square values		
		Stover Yield (t ha $^{-1}$)	Biological Yield (t ha^{1})	Harvest Index (%)
Replication	2	9.19	56.04	755.47
Treatment	15	0.43*	1.74*	86.58*
Error	30	0.18	0.79	63.03
CV (%)		13.43	16.52	20.23

*Significant at 5% level