MS THESIS

MD. MAHAMODUL HASAN

JUNE, 2011

RESPONSE OF IRRIGATED WHEAT TO THE PLACEMENT METHODS OF PRILLED AND SUPER GRANULAR UREA

MD. MAHAMODUL HASAN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY,

DHAKA-1207

JUNE , 2011

RESPONSE OF IRRIGATED WHEAT TO THE PLACEMENT METHODS OF PRILLED AND SUPER GRANULAR UREA

By

MD. MAHAMODUL HASAN
REGISTRATION NO. 05-1623

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

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

SEMESTER: JANUARY- JUNE, 2011

Approved by:

……………………………..
(Prof. Dr. Md. Fazlul Karim)

Supervisor

………………………..
(Prof. Dr. A.K.M Ruhul Amin)

Co-supervisor

…………………………………
(Prof. Dr. A. K. M. Ruhul Amin)
Chairman, Examination Committee
Department of Agronomy, SAU

CERTIFICATE

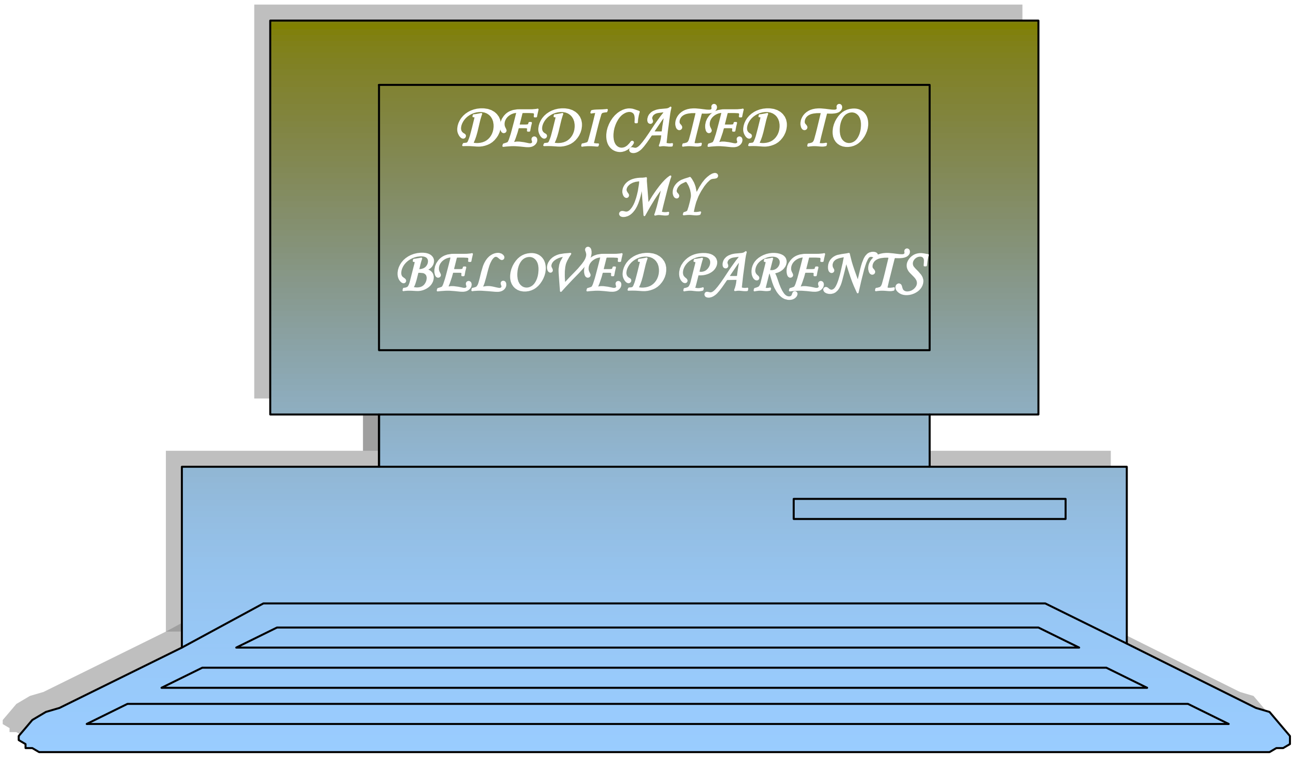
This is to certify that the thesis entitled, "**RESPONSE OF IRRIGATED WHEAT TO THE PLACEMENT METHODS OF PRILLED AND SUPER GRANULAR UREA"** submitted to the department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the results of a piece of *bona fide* research work carried out by **MD. MAHAMODUL HASAN,** Registration no.05-1623. 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.

(Prof. Dr. Md. Fazlul Karim)

Dated:

Place: Dhaka, Bangladesh **Supervisor**


DEDICATED TO
MY
BELOVED PARENTS

Acknowledgement

ALHAMDULILLAH, all praises are due to Almighty Allah ,The Great, Gracious and Merciful, Whose blessings enabled the author to complete this research work successfully.

The author is grateful to them all who made a contribution to this research work, although it is not possible to mention all by names.

In Particular, the author takes the opportunity to express his deepest sense of gratitude to his honorable Supervisor, Prof. Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his Co-operation, patient guidance, constructive comments,valuable suggestions and instructions throughout the progress of this research work and in preparation of this thesis.

The author takes an opportunity to express his profound gratitude and sincere appreciation to his Co-supervisor and Chairman Prof. Dr. A. K. M Ruhul Amin, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, as his creative suggestions, guidance and constant inspiration from beginning to the end of the work have greatly contributed to the completion of the study.

The author wishes to express his sincere appreciation and heartful indebetedness to all other teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for their valuable teaching and advice during study.

Special appreciation is also due to the friends namely, Kabir, Bashir, Nasir, Hasan, Mitu, Akram, Abdullah vi and relatives for their fellow feeling and encouragement during the study period.

The author appreciates the assistance rendered by the staff of the Department of Agronomy and Central Farm, Sher-e-Bangla Agricultural University, Dhaka-1207, who have helped him lot during the experimentation.

Lastly but not least the author can not but express his immense indebtedness, deepest sense of gratitude and profound respect to his parents for their great sacrifice, endless prayers, blessing and support to reach him at this level of education.

The author

RESPONSE OF IRRIGATED WHEAT TO THE PLACEMENT METHODS OF PRILLED AND SUPER GRANULAR UREA

ABSTRACT

A field experiment was carried out at the Agronomy Farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during rabi season of 2010-2011 to study the effect of prilled urea and urea super granule on the growth and yield of wheat under irrigated condition. The experiment consisted of sixteen treatments as T_1 =Prilled urea (PU) broadcasted@100 kg N ha^{-1} during sowing , T_2= PU placed in the side furrow@100kg N ha^{-1} during sowing, T_3=PU placed between two rows@100kg N ha^{-1} during sowing, T_4=PU & seed in the same furrow@100kg N ha^{-1} during sowing, T_5=Urea Super Granule (USG) at 5 cm depth as basal@75kg N ha^{-1}, T_6=USG placed at 5 cm depth at 10 DAS@75kg N ha^{-1}, T_7=USG placed at 5 cm depth at 20 DAS@75kg N ha^{-1}, T_8=USG placed at 5 cm depth at 30 DAS@75kg N ha^{-1}, T_9=USG placed at 10 cm depth as basal@75kg N ha^{-1}, T_{10}=USG placed at 10 cm depth at 10 DAS@75kg N ha^{-1}, T_{11}=USG placed at 10 cm depth at 20 DAS@75kg N ha^{-1}, T_{12}=USG placed at 10 cm depth at 30 DAS@75 kg N ha^{-1}, T_{13}=USG placed at 15 cm depth as basal@75 kg N ha^{-1}, T_{14}=USG placed at 15 cm depth at 10 DAS@75kg N ha^{-1}, T_{15}=USG placed at 15 cm depth at 20 DAS@75kg N ha^{-1} and T_{16}=USG placed at 15 cm depth at 30 DAS@75 kg N ha^{-1}. Application of PU and USG as nitrogen fertilizer had significant positive effect on growth, yield and yield contributing characters of wheat. The tallest plant (97.73 cm), maximum effective tillers $sprike^{-1}$ (6.67) and higher total dry matter (11.86 g $plant^{-1}$) were recorded in T_{11} (USG placed at 10 cm depth at 20 DAS@75 kg N ha^{-1}) than other treatments. This treatment also produced significantly higher grains $spike^{-1}$ (42.33), 1000-grains weight (40.11 g), grain yield (4.00 t ha^{-1}), straw yield (5.31 t ha^{-1}) and biological yield (9.31 t ha^{-1}) followed by T_{10} (3.80 t ha^{-1}) treatment. The highest harvest index (45.45%) was obtained from T_6 (USG placed at 5 cm depth 10 DAS@ 75 kg N ha^{-1}) treatment. The use of USG was found more effective to minimize production cost as well as increase yield. Hence the rate of N @ 75 kg N ha^{-1} in the form of USG along with other fertilizer may be considered as a suitable management for obtaining higher yield of irrigated wheat.

CONTENTS

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF APPENDICES

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Wheat (*Triticum astivum* L.) is one of the major cereal crops of the world ranking first both in acreage and production among the cereal crops. It provides more nourishment for the nation of the world than any other food crops. It supplies carbohydrate, protein, minerals and vitamin and preferable to rice for its higher seed protein content. Wheat seed contains 12% protein, 1.72% fat, 69.60% carbohydrates and 27.20% mineral matter (BARI, 1997). Bangladesh is a highly populated country and its population density is increasing day by day. Scarcity of food has become a chronic problem of this country. To mitigate the food shortages, measures should be taken to increase total food production. Since the area is fixed, the scope of horizontal expansion of cropping is limited. The shortage of food grains can not be easily met by growing rice alone. To solve the food problem more attention should be given to cultivate rice along with supplementary grain crops like wheat, maize and other cereals (Islam *et al*., 2012)..

In Bangladesh, wheat is the second important cereal crop next to rice. The area under wheat cultivation during 2009-2010 was about 3 lakh 73 thousand 538.1 hectare. producing 901 thousand m tons of wheat with an average yield of 2.28 ton ha^{-1} (BBS, 2011). Though wheat is an important cereal crop in Bangladesh, its average yield is low compared to that of some other wheat growing countries of the world. In Holland, United Kingdom, France and Norway the average yield of wheat is 7.8, 7.7, 6.2 and 4.4t ha^{-1}, respectively; whereas in Bangladesh, it is only 1.9 t ha^{-1} (FAO, 2006). Therefore, it is very important to increase the production of wheat in Bangladesh by increasing its yield. Wheat is adaptable to a wide range of soil and climatic conditions of Bangladesh and it gives good yield across the country. The yield of wheat can be augmented with the use of high yielding varieties and suitable agronomic practices.

Nitrogen fertilizer is an important input if wisely used but highly dangerous if wrongly applied. Nitrogen is considered to be the most important nutrient element for plants. Rate of N application has a great influence on growth, development and yield of wheat. Grain yield of wheat increases with increasing nitrogen level up to 120 kg ha^{-1} (Malik *et al.,* 1981). Among the fertilizers, nitrogen plays a vital role in producing higher grain yield. Among N fertilizers, prilled urea is a fast releasing nitrogen fertilizer which is usually broadcast and split, that causes considerable loss as ammonia volatilization, immobilization, denitrification and surface run of etc. On the other hand, deep placement of slow releasing nitrogenous fertilizer such as, urea supergranule (USG) reduces loss as well as increases its use efficiency (Mohanty *et al.,* 1989). Broadcast application of urea on the surface soil causes losses up to 50% but point placement of USG in 10 cm depth result negligible loss (Crasswell and De Datta, 1980).

Urea is the cheapest nitrogenous fertilizer containing high nitrogen (46%) and globally comprises more than 50% of inorganic N fertilizers used for agricultural production. Optimize fertilization strategies is a crucial issue in feeding the future world population in light of estimates that 70% of all plant nutrients at global level will come from fertilizers by the year 2020 (Ayoub, 1999). However, depending on soil and environmental conditions, these losses can be reduced by any or all of mixing the prills with the soil, using band or deep placement of them (Bouwmeester *et al*., 1985). Deep placement might be characterized by slower mineral N diffusion, possibly resulting in increase uptake and recovery of added N by the plant (Nyborg and Malhi, 1992). Given the significant improvement in crop production they can be achieved with the banding or nesting of urea prills (Malhi and Nyborg, 1992). Due to maximum utilization of nitrogen by the plant as when it required.So the use of USG could have a large potential for reducing the loss of reactive gaseous N species, especially NH_3, nitrogen oxides and nitrous oxide (Khalil 2009 a, b).

Work done by many researchers, especially by the International Fertilizer Development Center (IFDC), have conclusively demonstrated that compacted USG, that is, urea with 1–3 g granule, is an effective N source (Savant and Stangel, 1990). In general, one or more Urea Super Granule are deep placed (7–10 cm depth) by hand at the center of every four rice seedling hills in rice soils during or after rice transplanting gave maximum yield (Savant *et al.,* 1983).Savant and Stangel (1998) have shown that N loss is significantly reduced, which results in a significant increase in rice grain yield under flooded conditions compared with split applied Prilled Urea. Furthermore, the reason for producing USG is that it makes it easier for farmers to apply USG by hand. Use of USG has one great advantage that it requires only one-time application in rice or wheat cultivation.Whereas surface application of PU requires two to three split applications that can still result in significant N loss. The use of USG has been successfully promoted in several Asian countries, notably in Vietnam and Bangladesh. The Government of Bangladesh has announced that the use of USG will expand almost 1 million hectors of rice land (IFDC, 2007).

A recent study (Kapoor *et al*., 2008) showed that deep placement of USG-with DAP and KCl performed better than broadcast application of urea (three splits), DAP, and KCl for rainfed rice or wheat in a Vertisol. Significantly higher grain yields and straw yields, total N, P, and K uptake, and N and P use efficiencies were observed with deep placement of N compared to broadcast of N. The amount of N required on deep placed reduced nitrogen reguirement by 20-30% as compared with normal urea use.

Therefore, the present study was undertaken with the following objectives:

a) To compare the influence of PU and USG on the growth and yield of irrigated wheat.

b) To determine time and depth of placement of USG on the yield of yield compnents of irrigated wheat.

Chapter 2
Review of literature

CHAPTER 2
REVIEW OF LITERATURE

Wheat has been established as the second most economic food grain crop to minimize the gap between food production and import in Bangladesh. Urea is one of the most important fertilizers in Bangladesh. USG is getting tremendous attention especially in rice cultivation and other crops to its comparable use, influence of less requirement. The yield of crops is increased when USG is applied in time and optimum depth. Related research findings on the effect of time and depth of placement of USG on the growth, yield and yield components of wheat and related other crops have been reviewed in this chapter.

2.1. Effect of time of placement of PU and USG on different plant characters and yield of wheat and other related crops

2.1.1 Plant height

Mattas *et al*. (2011) studied the effect of increasing levels of nitrogen fertilization and its time of application on the growth, yield and N uptake of durum wheat in an experiment. Three levels of N (120, 150 and 180 kg ha^{-1}) were given in the main plots and three times of nitrogen application: 1/2 at sowing + 1/2 at CRI, 1/3 at sowing + 1/3 at CRI + 1/3 at boot stage and 1/3 at sowing + 1/3 at CRI stage + 1/3 at anthesis stage were used in the subplots. Increasing level of nitrogen significantly increased plant height.

Pasha (2005) reported that plant height was not significantly varied between two splits (one third N as basal + two third at first node stage) and three splits (half N as basal, one fourth N at tillering + one fourth N at tillering) of fertilizer.

Ananda (2004) reported that split application of N as half basal + one fourth at 30 DAS + one fourth at 60 DAS recorded maximum plant height of wheat. Wagan *et al*. (2002) conducted an experiment to assess the effect of source and schedule of nitrogenous fertilizer on wheat growth and yield contributing characters where variety Sarsabz was drilled to test various nitrogenous fertilizers (urea, ammonium nitrite and ammonium sulphate) applied in two and three splits with basal dose of P and K. The results revealed that nitrogen applied in three split doses significantly increased plant height.

Kumar *et al.* (1999) conducted a field experiment on sandy loam soils of kukumseri (Lahaul valley) of dry temperate high hills of Himachal Pradesh during 1993-94 and 1994-95. The experiment consisted of 5 levels of nitrogen (0, 45, 90, 135 and 180 kg N ha^{-1}) and 2 cutting management practices. It was observed that plant height of winter wheat increased with increasing rates of N up to 180 kg N ha^{-1} during both years.

A field experiment was conducted at the Institutional Farm, Junagadh, India during winter season of 1991-92. The soil was clay loam in texture, low in available nitrogen. phosphorous, potassium and zinc. It was observed that plant height of wheat increased with increasing rates of N up to 120 kg N ha^{-1} (Patel *et al.* 1995).

Awasthi and Bhan (1993) conducted a field experiment at the soil conservation and water management farm of the University at Kanpur, India for 2 consecutive winter (rabi) seasons of 1986-87 and 1987-88. The treatments consisted of 5 varieties of wheat (k65, k78, k72, k8430 and C 306) and 4 levels of nitrogen (0, 20, 40 and 60 kg N ha^{-1}). They observed that plant height of wheat increased significantly with increasing rates of N up to 60 kg N ha^{-1}.

Ahmed and Hossain (1992) observed that plant heights of wheat were 79.9 cm, 82.3 cm and 84.4 cm, with 45, 90 and 135 kg N ha^{-1}, respectively. Plant height increased with increased nitrogenous fertilizer doses.

Doyugan and Bongolan (1985) observed that basal application of nitrogen increased plant height but, did not enhance the production of panicle bearing calms and therefore, did not affect the yield performance of crops.

2.1.2 Number of effective tillers $plant^{-1}$

Mattas *et al*. (2011) studied the effect of increasing levels of nitrogen fertilization and its time of application on the growth, yield and N uptake of durum wheat in an experiment. Three levels of N (120, 150 and 180 kg ha^{-1}) was given in main plots whereas the three times of nitrogen application: 1/2 at sowing + 1/2 at Crown Root Initiation (CRI) stage, 1/3 at sowing + 1/3 at Crown Root Initiation + 1/3 at boot stage and 1/3 at sowing + 1/3 at CRI stage + 1/3 at anthesis stage were given in the subplots. Increasing level of nitrogen significantly increased the number of tillers and number of effective tillers.

Wagan *et al*. (2002) conducted an experiment to assess the effect of source and schedule of nitrogenous fertilizer on wheat growth and yield contributing characters, at Latif experimental farm, Sindh Agriculture University, Tandojam, Pakistan. Wheat variety Sarsabz was drilled to test various nitrogenous fertilizers (urea, ammonium nitrite and ammonium sulphate) applied in two and three splits with basal dose of P and K. The results revealed that nitrogen applied in three split significantly increased number of tillers as compared to two split applications. Among the sources of nitrogen, urea was ranked at first place as compared to ammonium nitrate and ammonium sulphate fertilizers for growth and yields contributing characters where they applied urea at sowing and irrigation.

Kumar *et al.* (1995) conducted a field experiment during the winter seasons of 1990-91 and 1991-92 at karmal with 4 levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported that productive tillers increased significantly with the increase of N doses from 0 to 120 kg ha^{-1}.

Patel and Upadhyay (1993) carried out an experiment during the winter season (rabi) of 1989-90 at College Farm, Anand, with 3 levels of N (90, 120 and 150 kg N ha^{-1}) and reported that number of effective tillers m^{-2} increased significantly increasing rates of N up to 120 kg N ha^{-1}.

Gami *et al*. (1986) found that application of 120 kg N per ha, half at sowing in seed rows + half side dressing at first irrigation (21 DAS) increased the plant height, spike length, effective tillers, spikelets per spike and grain weight and gave significantly higher yield (36.69 q/ha) as compared to half placed in furrows at sowing plus half as foliar spray at 45 days after sowing or two third placed in furrows at sowing plus one third as foliar spray 35 days after sowing on clayey soil at Junagadh (Gujarat, India).

2.1.3 Number of spikes plant^{-1}

Upadhyay and Tiwari (1996) conducted a field experiment involving two wheat cultivar (Sonalika and Lok 1) with 3 levels of N (90, 120 and 150 kg N ha^{-1}) and reported that nitrogen application up to 120 kg N ha^{-1} increases spikes number plant^{-1} compared with lower dose (90 kg N ha^{-1}). Application of N beyond 120 kg N ha^{-1} did not increase the value of this character.

Ayoub *et al.* (1994) conducted an experiment at Lods Agronomy Research Centre, Mc Gill University, Macdonald Campus and at the crop Federee research farm, Ste-Rosalie, Canada in 1990 and 1991 on 4 cultivars (0, 60, 120 and 180 kg N ha^{-1}) and reported that spikes m^{-2} increased with increasing N fertilizer.

Awasthi and Bhan (1993) carried out an experiment at Kanpur on 5 varieties of wheat (k65, k72, k78, k8430 and C 306) with 4 levels of nitrogen (0, 20, 40 and 60 kg N ha^{-1}) and reported that number of spikes m^{-2} increased significantly with increasing rates of N up to 60 kg N ha^{-1}.

Patra (1990) conducted a field experiment with two wheat varieties (Sonalika and Sagarika) under varied levels of N-fertilizer (40, 80 and 120 kg N ha^{-1}) and observed that the number of spikes m^{-2} increased significantly with increasing rates of N up to 120 kg N ha^{-1}.

2.1.4 Spike length

Three levels of N (120, 150 and 180 kg ha^{-1}) formed the main plots whereas the three times of nitrogen application: 1/2 at sowing + 1/2 at CRI, 1/3 at sowing + 1/3 at CRI + 1/3 at boot stage and 1/3 at sowing + 1/3 at CRI stage + 1/3 at anthesis stage were kept in the subplots. Increasing level of nitrogen from 120 to150 and to

180 kg ha^{-1} significantly increased the ear length and number of grains per ear and grain and straw yield (Mattas *et al.*, 2011).

Jaiswal and Singh (2001) conducted a field experiment during 1996-97 and 1997-98, in Faizabad, Uttar Pradesh, India. They reported that N through urea granule was applied as total point placement method by placing each ball of 1 g through applicator in the centre each among 4 hills at 5 cm depth and 8 days after transplanting rice. In this experiment deep placement of urea super granule effectively increased N use efficiency (31.7%) and panicle length compared to conventionally applied urea.

Kumar *et al.* (1999) conducted a field experiment on sandy loam soil of kukumseri (Lahaul valley) of dry temperate high hills of Himachal Pradesh, India during 1993-94 and 1994-95. The treatments consisted of 5 levels of N (0, 45, 90, 135 and 180 kg N ha^{-1}) and 2 cutting management practices. They observed that length of spike of winter wheat increased with increasing level of N. Maximum spike length was obtained at 180 kg ha^{-1} during both years.

Upadhyay and Tiwari (1996) carried out an experiment with 2 wheat varieties (Sonalika and Lok 1) under 3 levels of N (90, 120 and 150 kg N ha^{-1}). The experimental result showed that application of N up to 120 kg N ha^{-1} increased the spike length of wheat compared with lower dose (90 kg N ha^{-1}). Application of N beyond 120 kg N ha^{-1} did not increase the spike length.

A field experiment was conducted at the Institutional farm, Janagadh,India during winter (rabi) season of 1991-92 with 3 levels of N (90, 120 and 150 kg N ha^{-1}) and it was reported that significant increase in spike length of wheat was observed only up to the application of 120 kg N ha^{-1} (Patel *et al.* 1995).

2.1.5 Number of spikelets spike^{-1}

Kumar *et al.* (1999) were studied on sandy loam soils of kukumseri (Lahaul valley) of dry temperate high hills of Himachal Pradesh during 1993-94 and 1994-95 with 5 levels of N (0, 45, 90, 135 and 180 kg N ha^{-1}) and 2 cutting management practices. They reported that the number of spikelets spike^{-1} of winter wheat increased with the increase of N level. Highest spikelets spike^{-1} was obtained at 180 kg N ha^{-1}.

Dhuka *et al.* (1991) conducted a field experiment on wheat cv. GW 120 with 3 levels of N (40, 80 and 120 kg ha^{-1}) and reported that number of spikelets spike^{-1} was significantly increased by N application. Maximum spikelets spike^{-1} was obtained at 120 kg N ha^{-1}. A field experiment was conducted on; WH 283 wheat with 0, 40, 80 and 120 kg N ha^{-1}. Number of spikelets spike^{-1} increased with the increase of N level. Highest spikelets spike^{-1} was obtained at 120 kg N ha^{-1} .

Rekhi *et al*. (1989) conducted an experiment on a loamy sand soil with rice cv. PR 106 providing 0, 37.5, 75.0 or 112.5kg N ha^{-1} as urea super granules (USG) prilled urea (PU). PU was applied in three equal splits at transplanting, tillering and panicle initiation and USG was placed at 8-10 cm deep in alternate rows, equidistant from 4 hills. They found that PU produced the longest plant, higher number of panicle and higher amount of nitrogen uptake.

2.1.6 Number of grains spike^{-1}

Three levels of N (120, 150 and 180 kg ha-1) formed the main plots whereas the three times of nitrogen application: 1/2 at sowing + 1/2 at CRI, 1/3 at sowing + 1/3 at CRI + 1/3 at boot stage and 1/3 at sowing + 1/3 at CRI stage + 1/3 at anthesis stage were kept in the subplots. Increasing level of nitrogen from 120 to150 and to 180 kg ha-1 significantly increased the number of grains per ear (Mattas *et al*. 2011).

Bellido *et al.* (2000) carried out a field experiment during 1986 in Cordoba, southern Spain, on a vertisol (Typic Haploxerert) with 4 levels of N (0, 50, 100 and 150 kg N ha^{-1}). They observed that number of grains spike^{-1} of wheat increased significantly at the nitrogen rate 150 kg N ha^{-1}.

On black clayey soil at Indore (MP) under irrigated condition, split application of the recommended dose of 120 kg N per ha as 10-25 per cent at sowing, 50-60 per cent at CRI stage and 20-30 per cent at late jointing stage produced significantly higher number of effective tillers per meter spikelets, grains per spike, grain weight per spike compared to other combination of split application of nitrogen (Deshmukh *et al*., 1994).

2.1.7 1000-grain weight

Kumar *et al.* (1999) conducted a field experiment on sandy loam soils of kukumesi (Lahaul valley) of dry temperate high hills of Himachal Pradesh during 1993-94 and 1994-95 on winter wheat with 5 levels of nitrogen (0, 45, 90, 135 and 180 kg N ha^{-1}) and 2 cutting with increasing rate of up to 180 kg N ha^{-1}.

At Bangoli (MP) on a clay loam soil, Patel (1999) reported that application of N in a ratio of 50: 25: 25 per cent at sowing, 21 and 45 DAS, respectively recorded significant improvement in growth and yield parameters like 1000-grain weight, higher grain yield and straw yield as compared to other methods of nitrogen application.

A study conducted at Eastern Canada in clay loam soil by Ayoub *et al*. (1994) revealed that split application of nitrogen fertilizer (60% at sowing + 40% at heading) had little effect on yield but reduced the risk of lodging and caused an increased 1000- kernel weight, when compared with application of all the fertilizer nitrogen at sowing.

Patel and Upadhyay (1993) conducted an experiment with 3 levels of N (0, 120 and 150 kg N ha^{-1}) and reported that 1000-seed weight of wheat increased significantly with increasing rates of N up to 150 kg N ha^{-1}.

2.1.8 Grain and straw yield

Three levels of N (120, 150 and 180 kg ha^{-1}) formed the main plots whereas the three times of nitrogen application: 1/2 at sowing + 1/2 at CRI, 1/3 at sowing + 1/3 at CRI + 1/3 at boot stage and 1/3 at sowing + 1/3 at CRI stage + 1/3 at anthesis stage were kept in the subplots. Increasing level of nitrogen from 120 to150 and to 180 kg ha^{-1} significantly increased the number of grains per ear and grain and straw yield. The highest grain yield (58.23 t ha^{-1}) recorded at nitrogen level of 180 kg ha^{-1} was due to significant improvement in yield contributing characters (Mattas *et al*. 2011).

These wheat cultivars were grown individually in nine different locations (Yantai, Qingdao, Binzhou, Dezhou, Liaocheng, Zibo, Linyi, Taian, and Heze) representing different climatic variations across Shandong Province, China. The randomized plot area was 12 m, with two replicates. Total available nitrogen of 40 mg kg^{-1}, available phosphorus of 50 mg kg^{-1}, and available potassium of 70 mg kg^{-1} were contained in the 0-20 cm of testing soil. 60000 kg ha^{-1} organism fertilizer, 225 kg ha^{-1} ammonium hydrogen phosphate, 150 kg ha^{-1} urea, and 375 kg ha^{-1} potassium sulfate were applied before ploughing 225 kg ha^{-1} urea was topdressed before booting and another 75 kg ha^{-1} urea was topdressed during anthesis. Harvested seeds were used to analyze the stability time after storing for 3 months, (Tian *et al.* 2007).

Kulkami *et al*. (2005) carried out a field experiment at an agricultural college in Kolhapur, Maharashtra, India, during 1993-96 on rainfed upland rice (cv. RDN-185-2) grown on silty clay loam soil to investigate the utilization of prilled urea and urea super granules (USG) in single and split doses by deep placement at different crop growth stages. Among the ten different treatments of PUN and USGN, six were applied at two stages of crop growth, %z doses at sowing and remaining %2 at panicle stage, and USGN treatments were applied as full basal dose'at sowing. Grain yield was significantly increased by PU and USG application over control (no nitrogen).
Ananda (2004) reported that among split application of nitrogen, nitrogen applied as half basal + one-fourth at 30 DAS + one-fourth at 60 DAS recorded higher wheat grain and straw yields as compared to nitrogen applied as half basal + half at 30 DAS. Samra and Dhillon (2002) reported that application of nitrogen in two splits i.e. half at sowing and half at CRI stage remarkably improved the grain and straw yields of wheat on sandy loam soil at Ludhiana (Punjab) over all the other split application.

Application of nitrogen at 100 kg per ha half nitrogen as basal plus half nitrogen just after first irrigation as top dressing recorded higher grain and straw yields of wheat as compared to nitrogen top dressed before irrigation leading to more leaching loss beyond the crop root zone depth (Sarena and Jana, 2001).

Halvorson *et al.* (2000) carried out a field experiment during 1984 on a Temvik-Wilton silt loam soil located near Mandan, on spring wheat with 3 doses of N (0, 22 and 45 kg N ha^{-1}) and reported that increasing level of N gave significantly higher grain yield. Maximum grain yield was obtained at 45 kg N ha^{-1}. Bellido *et al.* (2000) carried out a field experiment during 1986 in Cordoba, southern Spain, on avertisol (Typic Haploxerert) with 4 levels of N (0, 50, 100 and 150 kg N ha^{-1}). They reported that grain yield of wheat increased significantly when the rate was increased from 100-150 kg N ha^{-1}.

Ahmed *et al*. (2000) revealed that USG was more efficient than PU at all respective levels of N in producing all yield components and in turn, grain and straw yields, placement of USG @160 kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) and it was statistically identical to that obtained from 120 kg N ha^{-1} as USG and significantly superior to that obtained from any other level and source of N.

Mishra *et al.* (1999a) conducted a field experiment in Bhubaneswar, Orissa, India and found that rice cv. Lalat was given 76 kg N ha^{-1} as USG at 0, 7, 14 or 21 DAT, and these treatments were compared with split application of prilled urea (PU) and an untreated control. Nitrogen increased plant height, panicle length and number of tillers hill^{-1}, N uptake and consequently, the grain and straw yields of lowland rice. Best results were obtained with USG applied 14 DAT.

Kumar *et al.* (1999) conducted a field experiment on sandy loam soils of kukumesi (Lahaul valley) of dry temperate high hills of Himachal Pradesh during 1993-94 and 1994-95. The treatments consisted of levels of N (0, 45, 90, 135 and 180 kg N ha^{-1}) and 2 cutting management practices. They reported that grain yield of winter wheat increased with an increase in N level from 0 to 180 kg N ha^{-1} and significantly highest yield was obtained when the crop was fertilizer with 180 kg N ha^{-1} during both the years.

Deor and Pathik (1997) reported that application of nitrogen not exceeding beyond 60 kg per ha applied in equal splits i.e. half N at sowing + half N one month after sowing on clay loam soil at Sunder Nagar (HP) caused enhancement in grain and straw yield as compared to full nitrogen applied at sowing.

Kumar *et al*. (1996) reported that application of USG in the sub-soil gave 22% higher grain yield than control. Dwivedi and Bajpai (1995) observed through using 0 to 90 kg N ha^{-1} as urea, USG+ urea or urea spray and they found that grain yield and net returns increased with the increased rate of N application and were highest with USG and lowest with urea spray.

Velu and Ramanathan (1994) found that grain yield, N use efficiency and N uptake were the highest with USG in all seasons. Dighe *et al*. (1994) noted that splitting of nitrogen fertilizer dose into three splits (10% nitrogen as basal + 60% nitrogen at CRI top dressed + 30% nitrogen at late jointing) plus basal P_2O_5 recorded the highest yield and was significant over three splits of nitrogen and phosphorus (10% N + 10% P_2O_5) as basal + (60% N + 60% P_2O_5) top dressed at CRI and (30% N + 30% P_2O_5) top dressed at late jointing stage in bunds. However, it was on par with 2 nitrogen split + basal P_2O_5 (50% N + full dose of P_2O_5 or basal + 50% N at CRI top dressed in bunds close to roots) on clayey soil at Indore (MP).

At Morena (UP) on sandy loam soil, application of urea as split, half of the total amount was applied as basal and remaining half applied after irrigation gave significantly higher yield than split application of urea before irrigation (Rajput and Verma, 1994). Stark and Tindall (1992) in their study opined that maximum spring wheat grain yield and test weight could be obtained by applying the bulk of seasonal nitrogen requirements at sowing and then applying single or double split nitrogen application at anthesis on stem elongation and anthesis.

Dhuka *et al*. (1992) on loamy sand soil at Junagadh (Gujarat) stated that application of nitrogen in three splits as half at basal + one-fourth top dressed at 21-25 DAS + one-fourth top dressed at 35-40 DAS increased the grain and straw yields by 49.9 and 23.9 per cent, respectively over no split and by 9.0 and 11.0 per cent over two splits (half N top dressed at 21-25 DAS plus half to N dressed at 35-40 DAS).

Agarwal and Sharma (1992) reported from an experiment with rice cv. Jaya applying 80 kg basal N ha^{-1} as urea, neem-cake-coated urea (NCU), Urea super granules

(USG) and urea treated with dicyandiamide (DCDU) 40, 80 or 120 kg urea as basal + top dressing or 40 kg DCDU as basal + 40kg urea as top dressing and concluded that grain yield was highest with 120 kg N applied as a basal + top dressing of urea, N uptake in grain was highest with 80 kg USG ha^{-1} applied as basal + top dressing.

Bhopal Singh and Singh (1991) recorded significant increase in grains per ear, grain weight per ear and grain yield with the application of 120 kg N per ha in three splits (25% at CRI, 50% at tillering and 25% at jointing) as compared to the recommended practice of N application (half N at sowing and half at first irrigation) on silty clay loam soil at Palampur.

Kumar *et al.* (1990) explained that USG as a source of nitrogen showed potential for improving nitrogen use efficiency in rice crops. Ameta and Singh (1990) observed that increasing fertilizer N application from 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 7^{l} compared to 4.39 t ha^{-1} from applying all N as basal dressing placement of 75 kg USG at 8-10 cm soil depth, 7 days a transplanting produced similar grain yield as application of 90 kg Plain Urea.

Singh and Mahaptra (1989) showed that USG gave the highest yield (3.8-4.0) and (4.1-4.2 t ha^{-1}) with 60 and 90 kg N ha^{-1} when it was placed at 8-10 cm depth in the centre of 4 hill in alternate rows 10 days after transplanting. Sahu and Mitra (1989) reported that higher grain yields were obtained with large granular urea (LGU) @ 60 or 90 kg N ha^{-1} applied in two splits (7 days after transplanting and panicle initiation stage) than with PU in two or three splits. They also reported that N application @ 30 kg ha^{-1} as USG gave higher yields than LGU or PU.

Reddy and Reddy (1989) carried out experiments in the dry seasons of 1986 the summer season of 1987. They observed that rice gave similar grain yields with 120kg N ha^{-1} as USG applied in 2 equal split dressing (basal and at the panicle initiation), 120 kg N ha^{-1} as PU applied in three equal split dressing, 90kg N ha^{-1} as USG either as a basal dressing or in 2 equal split dressing compared with 3.2 and 3.3 t, respectively without N.

Mirzeo and Reddy (1989) worked with different modified urea materials and level of N @ 30, 60 and 90 kg N ha^{-1}. They reported that root zone placement of urea super granules (USG) produced the highest number of tillers at 30 or 60 days after transplanting (DAT). Urea' Super granules (USG) gave 19.0% and 8.8% o more panicle t n^2 in 1983 and 7.6% and 8.4% more panicle m ^{z} in 1984 than neem coated urea or prilled urea, respectively. Deep placement of urea super granules gave 10.3% more grain yield than prilled urea. The straw yield was also the highest with urea super granules.

Sen *et al.* (1985) reported that the placement of USG at any time between o 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 USG 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.
Ali (1985) carried out a field trial with rice cv. BR -3 growing on gray flood plain and real brown terrace soils applying N as PU. USG or SCU immediately before or after transplanting or in 2-3 split. It was reported that deep point placement of USG was superior to 2 or 3 application of PU on both soil. The superiority of USG was more pronounced boro than aus or transplant aman season.

Prilled urea (75 kg N ha^{-1}) was applied in two or three splits at planting, 5 days after transplanting 10 DAT and 15 DAT with 50+25+25% splits or four equal splits. Ramaswamy *et al*. (1985) observed that grain yield was maximum(5.4 t ha^{-1}) with three splits and was significantly superior to that of check.

2.2. Effect of depth of placement of PU and USG on different plant characters and yield of wheat and other related crops

2.2.1 Plant height

Rahman (2007) found that the effect of depth at 15 cm of placement of USG significantly influenced all growth characters of rice and the yield attributes except plant height. Siddika (2007) conducted an experiment by using prilled urea and urea super granules in transplanted aman rice and found that N-use efficiency was higher from USG in compared to prilled urea.

Alam (2002) found that plant height of boro rice increased significantly with the increase level of USG/4 hills. Akhter (1999) observed that the placement of USG @2 granules/4 hills significantly influence the plant height of T. aman rice. Sarder *et al*. (1988) observed that 94.8 kg N ha^{-1} as basal dose of urea, super granule (USG) produce taller plant and longer panicle of wetland rice than the other urea level.

2.2.2 Tillering pattern

Jee and Mahapatra (1989) also observed that number of panicles m^{-2} were significantly higher @ 90 kg ha^{-1} as deep placed USG than split application of urea. Nitrogen fertilizer use efficiency is relatively low in irrigated rice because of rapid N losses from volatilization and denitrification in the soil (De Datta and Buresh, 1989).

Mirzeo and Reddy (1989) worked with different modified urea material and levels of N at the rate of 30, 60 and 90 kg ha^{-1}. They have reported that root zone placement of USG produced the highest number of tiller 30 or 60 DAT. Urea super granules gave 14.0 and 8.8% more panicle m^{-2} in 1984 than neem coated urea (NCU) or PU, respectively.

Raman *et al.* (1989) mentioned that the number of panicles m^{-2} inc eased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as urea super granule (USG). Singh and Singh (1986) worked with different levels of nitrogen as USG @ 27.54- and 87 kg ha^{-1}. They reported that number of tillers m^{-2} increased with increasing nitrogen fertilizer.

2.2.3 Panicle length

Patel and Mishra (1994) carried out an experiment on rice cv. IR36 and were given 0, 30 0 or 90 kg N ha^{-1} urea super granules (USG). Urea super granules (USG) as placed 5-10 cm deep a week after transplanting, they showed that N rate had no significantly effect on panicle length, percent sterility, and harvest index.

2.2.4 Grains panicle-^{1} and 1000-grain weight

Thakur (1991) 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 $unit^{-1}$ area, panicle weight, number of grain $panicle^{-1}$, 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.

Sen and Pandey (1990) carried out a field trial to study the effect of placement USG (5, 10 or 15 cm deep) on rice yields of tall long duration Mahsuri and dwarf, short duration Madhuri. They revealed that Mahsuri had significantly LWer yield, panicle $m^{-2,}$ panicle length and weight, filled spikelets $panicle^{-1}$ 1000 -grain weight than Madhuri, probably due to Mahsuri's long duration.

2.2.5 Grain and straw yield

Sarker *et al*. (2012) conducted an experiment to find out the effect of Urea Super Granule (USG) on cabbage. There were five treatments viz. T_1: recommended nitrogen (N) dose as prilled urea (PU), T_2: recommended N dose as USG, T_3: 10% less than recommended dose of N as USG, T_4: 20% less than recommended dose of N as USG, and T_5: farmers practice (average of 20 farmers N dose used as PU) used in the experiment. Results revealed that yield of cabbage increased significantly due to application of USG over PU. The highest head yield of cabbage 92.04 and 91.36 t ha^{-1} were obtained from the USG (recommended dose) in 2007-08 and 2008-09, respectively which was statistically similar with USG 10% less than recommended dose (84.78 t ha-1) instead of traditional PU. The treatments T3 and T_4 were found more effective over PU, and N loss was also minimum than that of prilled urea where 10-20% N fertilizer could be saved by using USG instead of traditional PU.

Khalil *et al*. (2011) conducted an experiment on the impact of urea prills (1-2 mm) uersus urea supergranules (USG, ~10 mm), placed at different depths, on the growth and nitrogen (N) use efficiency of spring wheat was investigated under greenhouse conditions. The amount of fertilizer N^{15} derived from either form was 50% greater in the top soil than at lower depths. The comparatively slower release and distribution of USG-N resulted in enhanced dry mater production and fertilizer-N uptake during the later growth stages that were also associated with a higher translocation of fertilizer N^{15} into the grain (34.9% versus 28.7% for the prills). Deeper placement of USGs (5.0-7.5 cm) resulted in greater fertilizer-N recovery in the crop (70.5-78.0%) compared to the use of prills (56.6%). Our results strongly suggest that the proper application of USGs can increase yields and fertlizer-N utilization of wheat and simultaneously decrease N-losses compared to equivalent use of prills, and therefore presents important agronomic advantages.

Hussain *et al*. (2010) conducted an experiments at the Farming Systems Research and Development (FSRD) site, Palima, Tangail to evaluate the efficiency of USG application in comparison with prilled urea on the yield and yield attributes of cabbage (cv. Atlas-70). There were five treatments, $T_1 = N_{195}$ (recommended N dose for HYG, used as prilled urea), $T_2 = N_{195}$ (recommended N dose for HYG, used as USG), $T_3 = N_{175}$ (N 10% reduction of recommended N dose as USG), $T_4 = N_{155}$ (N 20% reduction of recommended N dose as USG), and $T_5 = N_{105}$ (Farmers' N dose used as prilled urea). Treatments T_1-T_4 received recommended dose of other nutrients ($P_{56}K_{162}S_{13}Mo_{0.6}CD_{3t}$) and T_5 received $P_{25}K_{90}S_0Mo_0CD_{51}$ Yield and yield-contributing characters of cabbage significantly responded to the application of USG. The highest head yield (78.1 t/ha) was obtained with the recommended dose of N as USG, and 10% (77.1 t/ha), and 20% (72.0 t/ha) less than the recommended dose of N as USG also produced higher yield than recommended prilled urea-N.

Hasan (2007) found that the effect of level of USG significantly influenced all the yield attributes except weight of 1000-grain. Grain and straw yields were found the highest (5.20 and 7.45 t ha^{-1}, respectively) from the level of USG @3 pellets/4 hill or 90 kg N ha^{-1}as USG.

Khalil *et al*. (2006) reported that the urea is the cheapest nitrogenous fertilizer and covers around 50% of the other inorganic N fertilizers used for agricultural production in the world. Efforts are being continuing to increase N utilization efficiency and to minimize its loss from agroecosystems through either developing improved management practices or limiting its release and transformations by chemical means. Research findings revealed slow release and urease/nitrification inhibition characteristics of large urea granules. Thus, we compared the influence of prilled urea (PU) mixed into soil with urea super granules (USG, ~0.70 g), which was point-placed either at 7.5 cm (experiment 1) or at 2.5, 5.0 and 7.5 cm soil depths (experiment 2) on the distribution of fertilizer N, yield response and N recovery by spring wheat in a loess silt loam using ^{15}N isotope technique. Both experiments were carried out under greenhouse conditions using polyvinyl boxes (110 cm x 70 cm x 40 cm).

Bowen *et* al. (2005) conducted 531 on-farm trials during *Boro* and *Aman* season in 7 districts of Bangladesh from 2000-2004. The results showed that UDP (Deep placement of urea super granules) increased grain yield by 1120 kg ha^{-1} and 890 kg ha^{-1} during *Boro* season and *Aman* season, respectively.

Miah *et al.* (2004) found that the values of the parameters measured were higher with application of urea super granules compared to application of urea. Dash *et al*. (2003) reported that deep placement of 76 kg USG ha^{-1} at 5 cm soil produced: significantly higher grain (43.1 q ha^{-1}) and straw (47.8 q ha^{-1}) with highest mean N use efficiency (24.13 kg grain kg^{-1} N applied). The study suggested that 76 kg N ha^{-1} is the optimum rate of N as USG.

Ahmed *et al*. (2000) conducted an experiment during the kharif season of 1998 at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the effect of point placement of urea super granules (USG) and prilled urea (PU). USG and PU were applied @ 40, 80, 120 and 160 kg N ha^{-1}. They found that placement of USG @ 160 kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha' as USG and significantly superior to that obtained from any other level and source of N.

Mishra *et al.* (1999b) reported that the N use efficiency of rice increased from 18 kg grain/kg N applied as PU to as high as 26 kg grain/kg N applied as USG. Similarly, the relative efficiency of USG was increased by 40% over PU. The apparent N recovery in rice also increased from 21% for PU to 40 % for USG. Here Rice showed a greater response to N upon USG placement than split application of PU.

The efficiency is further improved if hole is properly closed immediately after deep point placement of USG as observed by Bhuiyan *et al.* 1998. They also concluded that economic benefit of USG relative to PU was very high during the boro season than the transplant aman season.

Vijaya and Subbaiah (1997) showed that plant height, number of tillers, root length, number and weight of panicles, dry matter and grain yield of rice increased with the increasing urea super granules size and were greater with the deep placement method of application both N and P compared with broadcasting.

Swain *et al*. (1995) evaluated the performance of USG application methods in lowland transplanted rice. He reported that USG gave higher grain and straw yield. Singh *et al.* (1993) revealed that grain yield increased with increase rate of N application and were the highest with deep placed USG.

Bhardwaj and Singh (1993) carried out an experiment on flooded rice, using 84 or 112 kg N ha^{-1} as urea super granules (USG) was placed at 10 cm depth. They reported that the placement of 84 kg N as USG produced a grain yield of 6.8 t ha^{-1} which was similar to 112 kg USG placing.

Johnkutty and Mathew (1992) conducted an experiment on rice cv. Jyothy during rainy mason and reported that 84 kg N ha^{-1} as urea super granules (USG) gave higher yield. Singh and Pal (1991) studied the effect of sources and level of N on the yield, and N uptake of rice and reported that yield, yield attributes and N uptake were affected significantly due to sources and level of N. Deep of USG showed the highest grain yield (2.29 t ha^{-1}) followed by 2.43, 2.32 and 2.15 t ha^{-1} with scu, massorie rock phosphorus-coated urea and PU, respectively.

Satrusajang *et al.* (1991) studied the effect of nitrogen and sulphur fertilizers on yields of rain fed low land rice. They found that rice yield was statistically greater for deep placement of urea as USG than all other nitrogen fertilizer. Sarker and Bastia (1991) studied the method of application of USG in low land rice soil and showed that USG gave higher yield than PU when USG was placed at midway between every alternate 4 hills. They also recorded 2.10 t ha^{-1} mean grain yield without nitrogen and the nitrogen applied in the forms of PU and USG produced 2.66 and 3.89 t ha^{-1} mean grain yield respectively. N uptake was the highest with USG.
Ameta and Singh (1990) observed that increasing fertilizer N application from 30 to 24 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) 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 USG at 8-10 cm soil depth, 7 days after transplanting produced similar grain yield as application of 90 kg plain urea.

Dhane *et al.* (1989) stated that deep placed urea super granules (USG) significantly increased grain and straw yields of rice. Das (1989) reported that the dry mater yield, N uptake and grain and straw yield of rice were higher with application of USG. Mohanty *et al.* (1989) observed that the 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. Deep placement of USG proved superior to PU.

Chauhan and Mishra (1989) found that application of nitrogen @ 20, 80, 112 kg ha^{-1} as urea super granules (USG) gave yields 4.8, 4.86 and 5.17 t ha^{-1}. Patel and Desai (1987) carried out an experiment on rice applying N @58, 87 or 116 kg ha^{-1} as urea super granules (USG). At the rate of 58 kg ha^{-1} N as urea super granules placed at 10-12 cm depth gave the higher yield (4.38 t ha^{-1}). He also observed that the rate of 58 kg N ha^{-1} as urea super granules aced 10-12 cm depth gave the highest yield (4.34 t ha^{-1}) compared to any other rate.

An experiment was conducted by Rao *et al.* (1986) on rice where 80 kg N ha^{-1} was-applied as urea at transplanting or in 2 split dressing and 56 or 80 kg N ha^{-1} as USG placed at 8-10 cm depth in between the hills, gave paddy yields of 4.33, 4.87, 4.91 and 5.45 t ha^{-1}, respectively compared to 3.52 t ha^{-1} without N. The USG form was found the most effective in increasing DM production.

Rambabu *et al.* (1983) reported that of various form and methods of application of N fertilizers to rice grown under flooded conditions, placement of N as USG (1 g sizes) in the root zone at transplanting was most effective in increasing production, rice yield, N uptake and apparent recovery of applied N, followed by SCU incorporated before transplanting. Yield and N recovery were lowest with urea applied as basal drilling.

Apparao (1983) pointed out deep placement of 50 kg N ha 7^{l} as urea super granules (USG) gave significantly the paddy yields compared with urea applied basally or in 3 split applications. Deep placement of USG is more effective in terms of yield than broadcast application of urea for wetland rice (Savant *et al*., 1983)

From the reviews cited above it is clear that urea super granules (USG) have pronounced influence on the yield contributing characters and yield of wheat plant. Many research workers reported that time and depth of USG placement had different effects on crop characters and yield of wheat and also showed the higher N-Use efficiency. Wheat yield can also be greatly increased by split application of nitrogen compared with application of entire nitrogen at time. Timing of PU and USG placement under Bangladesh condition especially with irrigated wheat deserves due attention. Thus there may have enough scope of investigation on the effect of time and depth of placement of PU and USG in favour of yield improvement of irrigated wheat.

Chapter 3

Materials and Methods

CHAPTER 3
MATERIALS AND METHODS

This chapter provides a brief description of plant materials, experimental site, soil type, weather condition, land preparation, fertilizer application, experimental design layout, collection of data, method of intercultural operations, crop harvesting and statistical analysis etc. under the following heads.

3.1 Description of the experimental site

3.1.1 Duration and location

The experiment was conducted at the Agronomy Farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from November 2010 to March 2011. Geographically the experimental field is located at $23^0 74'$ N latitude and $90^0 35'$ E longitude at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone (AEZ) 28 of Madhupur Tract (UNDP and FAO, 1988).

3.1.2 Soil

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land, fertile, well drained and having p^H 5.8. The physicochemical property and nutrient status of soil of the experimental plots are given in Appendix 1a, 1b and 1c.

3.1.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature recorded by the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka during the period of study have been presented in Appendix II.

3.2 Experimental treatments

Nitrogen management: 16

T_1: Prilled urea (PU) broadcasted @100 kg N ha^{-1} during sowing

T_2: PU placed in the side furrow @100 kg N ha^{-1} during sowing

T_3: PU placed between two rows @100 kg N ha^{-1} during sowing

T_4: PU & seed in the same furrow @100 kg N ha^{-1} during sowing

T_5: Urea Super Granule (USG) at 5 cm depth as basal @75 kg N ha^{-1}

T_6: USG placed at 5 cm depth at 10 DAS @75 kg N ha^{-1}

T_7: USG placed at 5 cm depth at 20 DAS @75 kg N ha^{-1}

T_8: USG placed at 5 cm depth at 30 DAS @75 kg N ha^{-1}

T9: USG placed at 10 cm depth as basal @75 kg N ha^{-1}

T10: USG placed 10 cm depth at 10 DAS @75 kg N ha^{-1}

T11: USG placed at 10 cm depth at 20 DAS @75 kg N ha^{-1}

T12: USG placed at 10 cm depth at 30 DAS @75 kg N ha^{-1}

T13: USG placed at 15 cm depth as basal @75 kg N ha^{-1}

T14: USG placed at 15 cm depth at 10 DAS @75 kg N ha^{-1}

T15: USG placed at 15 cm depth at 20 DAS @75 kg N ha^{-1}

T16: USG placed at 15 cm depth at 30 DAS @75 kg N ha^{-1}

3.3 Plant materials

The crop used in this study was bread wheat having semidwarf high yielding characteristics. The wheat variety i.e. BARI Gom-21 (Shatabdi) was used as plant materials which was tolerant to diseases and pests. This variety is also suitable for late sowing condition. Seeds were collected from the Agronomy Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Germination test of seed was done in the laboratory before sowing and germination was found to be 95%. The characteristics of the variety used are as follows.

Shatabdi (BARI GAM-21)

Shatabdi was developed by BARI and released in 2000. It is a heat tolerant variety. This variety attains a height of 90-100 cm and takes 105-112 days to complete life cycle and is resistant to leaf rust and leaf spot disease. Number of tillers hill^{-1} is 4-6. It takes 65-69 days to heading and yield varies between 3.6-5.0 t ha^{-1}.

3.4 Experimental design and layout

The experiment consisted of 16 treatments and was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole experimental area was divided into three equal blocks. Each block was then further divided into 16 plots where 16 treatments were allotted at random. Thus there were 48 (16 × 3) unit plots altogether in the experiment. The size of each unit plot was 3 m × 3 m. Plot to plot and block to block distance were 1.5 m and 1.5 m distance respectively.

3.5 Land preparation

The land of the experimental field was first opened on November 5, 2010 with a power tiller. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The soil was treated with insecticides at the time of final ploughing. Insecticides was used to protect young plants from the attack of mole cricket, ants, and cutworms.

3.6 Fertilizer application

Fertilizer were applied during final land preparation at the rate of BARI recommended dose as 217 kg ha^{-1} prilled urea, 180 kg ha^{-1} TSP, 50 kg ha^{-1} MoP, 120 kg ha^{-1} Gypsum and urea super granule was applied as per treatments in each plot. The nitrogen rate for USG was 75 kg ha^{-1} .

3.7 Seed treatment

Seeds were treated with Vitavex-200 @0.25% before sowing to prevent seeds from the attack of soil borne disease.

3.8 Seed sowing

Seeds were sown on 29 November 2010 continuously in various depth apart rows opened by specially made an iron hand tine. The seed rate was 120 kg ha^{-1}. After sowing, the seeds were covered with soil and slightly pressed by hands.

3.9 Intercultural operations

3.9.1 Thinning

Emergence of seedling was completed within 10 days after sowing. Over crowded seedlings were thinned out for two times. First thinning was done after 15 days of sowing which is done to remove unhealthy and lineless seedlings. The second thinning was done 10 days after first thinning keeping one or two or three healthy seedlings in each hill according to the treatment.

3.9.2 Weeding

Weeding was done regularly to keep the plots free from weeds and to keep the soil loose and aerated.

3.9.3 Irrigation

The first irrigation was done at 21 DAS i.e, at crown root initiation (CRI) stage. Proper drainage system was also developed for draining out excess water.

3.9.4 Disease and pest management

The experimental crop was not infected with any disease and no fungicide was used. Mole cricket and cutworm attacked the crop during the early growing stages of seedlings. Spraying Pyriphos controlled these insects. The insecticide was sprayed three times at seven days interval.

3.10 Post-harvest operation

After harvesting, crop of each plot was dried separately. After that, threshing, cleaning and drying of grains were done separately plot-wise. Then the grain and straw weights of each plot were recorded. Sample plants were processed in a similar way.

3.11 The recording of data

Ten plants were randomly selected from each plot prior to harvesting for collection of data on plant characters, grain yield and its components. Data were recorded on the following characters.

3.12 Plant growth, yield and yield contributing characters

a) Plant height (cm)

b) Tillers hill^{-1}

c) Effective tillers hill^{-1}

d) Non-effective tillers hill^{-1}

e) Dry weight of root (g plant^{-1})

f) Dry weight of shoot (g plant^{-1})

g) Total dry matter (TDM) (g plant^{-1})

h) Length of spike (cm)

i) Grains spike^{-1}

j) Number of Filled grain spike^{-1}

k) Number of Unfilled grain spike^{-1}

l) 1000- grain weight (g)

m) Grain yield (t ha^{-1})

n) Straw yield (t ha^{-1})

o) Biological yield (t ha^{-1})

p) Harvest index (%)

3.13 A brief outline of the procedure of data recording

a) Plant height (cm)

Plant height was measured in centimeter by a meter scale at 30, 45, 60, 75 DAS and harvest from the ground to the top of the main shoot and the mean height was expressed in cm.

b) Tillers hill^{-1}

Number of total tillers hill^{-1} were counted at 30, 45, 60, 75 DAS and at harvest from pre selected ten hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting

c) Effective tillers hill^{-1}

The tiller which had at least one panicle was considered as effective tiller. The number of effective tillers of 10 hills was recorded and expressed as effective tillers hill^{-1}.

d) Non-effective tillers hill^{-1}

The tiller having no panicle was regarded as non-effective tiller. The number of non-effective tillers of 10 hills^{-1} was recorded and expressed as non-effective tillers hill^{-1}

e) Dry weight of root (g plant^{-1})

Immediately after harvest of 5 plants, the roots were cleaned thoroughly by washing with water. Roots were oven dried for 72 hours at 80°C. Immediately after oven drying, the dried roots were weighed and the dry matter content of the roots was recorded and converted to g plant^{-1}.

f) Dry weight of shoot (g plant^{-1})

The plant dry matter weight was taken by oven dry method. Ten plant samples randomly collected from each plot during harvest. They were gently washed to remove sand and dust particles adhere to the plants. Then the water adhere to the plant were soaked with paper towel. After then the samples were kept in an oven at 80°C for 72 hours to attain constant weight and the dry weights were recorded and converted to g plant^{-1}.

g) Total dry matter (TDM) (g plant^{-1})

The total dry matter production was calculated from the summation of dry matter weight of roots and shoots and the weight was expressed in g plant^{-1}.

h) Length of spike (cm)

Length of spike was measured in centimeter (cm) scale from randomly selected ten spikes. Mean value of them was recorded.

i) Grains spike^{-1}

Number of grain spike^{-1} was recorded after harvesting of the crop from the randomly selected ten plants. The grain spike^{-1} was calculated from their mean values.

j) Number of Filled grain spike^{-1}

Grain was considered to be filled if any kernel was present there in. The number of total filled grain present on each spike was recorded.

k) Number of Unfilled grain spike^{-1}

Unfilled grain means the absence of any kernel inside in and such grain present on each spike were counted.

l) 1000- grain weight (g)

One thousand grains were randomly counted and selected from the stock seed and weighed in gram by digital electric balance. It was expressed as 1000-seed weight in gram (g)

m) Grain yield (t ha^{-1})

Grains obtained from each unit plot were sun dried and weighed carefully. The dry weights of grains were adjusted at 12% moisture and converted to t ha^{-1}.

n) Straw yield (t ha^{-1})

The weight of straw obtained from each unit plot after proper sun drying and converted to t ha$^{-1.}$

o) Biological yield (t ha^{-1})

Grain and straw yields are altogether regarded as biological yield. The biological yield was calculated with the following formula-

Biological yield= Grain yield + Straw yield.

p) Harvest index (%)

Harvest index is the ratio of economic yield to biological yield and was calculated with the following formula-

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

3.14 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed in MSTAT-C computer program (Russell, 1986). The mean values for all the parameters were calculate and the analysis of variance for the characters was accomplished by Duncan's Multiple Range Test (DMRT) at 5% levels of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER 4
RESULTS AND DISCUSSION

The experiment was conducted to study the effects of prilled urea (PU) and urea super granule (USG) in relation to its plant growth, yield and yield contributing characters of irrigated wheat. Results of the present study have been presented and discussed in this chapter. The summary of analysis of variance has been presented in Appendix III to VI. Results are also presented in Tables 1 to 6. Results and discussion of the study are as detailed below.

4.1 Effect of prilled urea and urea super granule management on growth of wheat

4.1.1 Plant height (cm)

Plant height was affected significantly by the effect of different placement and time of prilled urea and urea super granule application at different days after sowing in Appendix IV and Table 1. The plant height data was recorded at 15 days interval from 30 DAS to harvest.

Plant height increased progressively over time attaining the height at harvesting stage. The rate of increase varied depending on the growth stage.

The treatment T_{11} (USG placed at 10 cm depth at 20 DAS) produced significantly tallest plants of 31.85, 47.61, 69.61, 88.06 cm and 97.32 cm at 30, 45, 60, 75 days after sowing and harvest, respectively. USG was found better for plant height compared to those of prilled urea treatmetns.Significantly shorter plants were observed in T_1 (prilled urea broadcast) treatment at all growth stages. The influence of USG was confirmed by Rekhi *et al*. (1989). Mattas et al. (2011) reported that increasing level of USG with the increasing sowing date significantly increased the plant height.

Table 1. Effect of prilled urea and urea super granule management on the plant height of wheat at different days after sowing

Treatments	Plant height (cm)				
	30	**45**	**60**	**75**	**At harvest**
T_1	22.89 f	38.77 e	60.61 c-e	77.62 d	85.62 e
T_2	25.30 de	40.94 de	59.79 de	80.07 b-d	91.04 bc
T_3	23.86 ef	39.64 de	57.90 e	78.91 cd	86.30 de
T_4	25.93 c-e	42.02 b-e	63.98 b-d	81.16 b-d	91.94 bc
T_5	29.13 b	45.16 a-c	67.16 ab	83.99 ab	94.99 ab
T_6	25.95 c-e	41.95 b-e	63.95 b-d	80.67 b-d	91.62 bc
T_7	29.14 b	45.33 ab	67.04 ab	83.94 ab	94.98 ab
T_8	27.80 bc	43.28 b-d	65.35 a-c	82.32 b-d	93.32 bc
T_9	28.65 b	44.75 a-c	67.00 ab	83.62 a-c	94.95 ab
T_{10}	25.22 de	41.44 c-e	63.07 b-d	80.32 b-d	91.32 bc
T_{11}	31.85 a	47.61 a	69.61 a	88.06 a	97.73 a
T_{12}	29.11 b	44.97 a-c	66.97 ab	84.16 ab	95.16 ab
T_{13}	27.09 b-d	43.02 b-d	64.94 a-c	82.07 b-d	92.98 bc
T_{14}	23.96 ef	39.83 de	61.67 c-e	78.83 cd	89.62 cd
T_{15}	29.12 b	44.94 a-c	67.02 ab	83.99 ab	94.99 ab
T_{16}	27.14 b-d	43.07 b-d	65.33 a-c	82.01 b-d	93.06 bc
$S\bar{x}$	**0.675**	**1.119**	**1.538**	**1.453**	**1.217**
CV (%)	**4.33**	**4.52**	**4.13**	**3.07**	**2.28**

T_1: Prilled urea (PU) broadcast@100 kg Nha^{-1} during sowing
T_2: PU placed in the side furrow@100 kg Nha^{-1} during sowing
T_3: PU placed between two rows@100 kg Nha^{-1} during sowing
T_4: PU & seed in the same furrow@100 kg Nha^{-1} during sowing
T_5: USG at 5 cm depth as basal@75 kg N ha^{-1}
T_6: USG placed at 5 cm depth at 10 DAS@75 kg Nha^{-1}
T_7: USG placed at 5 cm depth at 20 DAS@75 kg Nha^{-1}
T_8: USG placed at 5 cm depth at 30 DAS@75 kg Nha^{-1}
T_9: USG at 10cm depth as basal@75 kg Nha^{-1}
T_{10}: USG at 10cm depth at 10 DAS@75 kg Nha^{-1}
T_{11}: USG at 10 cm depth at 20 DAS@75 kg Nha^{-1}
T_{12}: USG at 10cm depth at 30 DAS@75 kg Nha^{-1}
T_{13}: USG placed at 15 cm depth as basa@75 kg Nha^{-1}l
T_{14}: USG placed at 15 cm depth at 10 DAS@75 kg Nha^{-1}
T_{15}: USG placed at 15 cm depth at 20 DAS@75 kg Nha^{-1}
T_{16}: USG placed at 15 cm depth at 30 DAS@75 kg Nha^{-1}

4.1.2 Total tillers hill^{-1}

The analysis of variance results regarding the number of tillers hill^{-1} at 15 days interval from 30 to 75 DAS and at harvest is given in Appendix V and Table 2. That number of total tillers hill^{-1} was affected significantly by the application of prilled urea and urea super granule. Regardless of treatment differences, total number of tillers hill^{-1} of wheat increased up to 75 days after sowing and then decreased (Table 2). Treatment T_{11} (USG placed at 10 cm depth at 20 DAS) produced significantly the maximum tillers hill^{-1} at all growth stages (2.03, 3.70, 5.93, 7.63, and 7.13 at 30, 45, 60, 75 DAS and harvest, respectively .USG placed at 10 cm depth either 10 DAS (T_{10}) or 30 DAS (T_{12}) gave statistically similar number of tillers hill^{-1} at all growth stages and those were found to be better than the treatments of PU. Significantly lower tillers hill^{-1} (0.70, 1.70, 3.20, 4.50 and 4.00) were recorded from T_1 (prilled urea broadcasted) treatment at all the growth stages, respectively.

Table 2. Effect of prilled urea and urea super granule managements on tillers hill^{-1} of wheat at different days after sowing

Treatments	Number of tillers hill^{-1}				
	30	**45**	**60**	**75**	**At harvest**
T_1	0.70 f	1.70 g	3.20 g	4.50 h	4.00 f
T_2	1.17 de	2.13 e-g	3.60 e-g	5.00 gh	4.67 e
T_3	1.07 e	2.40 d-f	3.87 e-g	5.70 e-g	5.33 de
T_4	1.47 c	2.13 e-g	4.27 de	6.20 d-f	5.67 cd
T_5	1.03 e	2.37 d-f	3.70 e-g	5.50 fg	5.00 de
T_6	1.50 c	2.83 b-d	4.27 de	6.20 d-f	5.67 cd
T_7	1.77 b	3.10 bc	3.87 e-g	5.70 e-g	5.43 cd
T_8	1.20 de	2.53 c-e	3.47 fg	5.33 f-h	5.00 de
T_9	1.20 de	2.87 b-d	5.00 bc	6.43 c-e	6.07 bc
T_{10}	1.83 b	3.17 ab	5.53 ab	7.37 ab	6.83 a
T_{11}	2.03 a	3.70 a	5.93 a	7.63 a	7.13 a
T_{12}	1.47 c	2.80 b-d	5.53 ab	7.00 a-d	6.47 ab
T_{13}	1.07 e	2.07 e-g	4.60 cd	6.73 a-d	6.47 ab
T_{14}	0.80 f	1.80 fg	4.03 d-f	7.23 a-c	6.90 a
T_{15}	1.37 cd	2.37 d-f	5.20 bc	6.47 b-e	6.10 bc
T_{16}	1.17 de	2.50 c-e	4.60 cd	6.17 d-f	5.63 cd
S$\bar{x}$	**0.068**	**0.191**	**0.224**	**0.282**	**0.217**
CV (%)	**9.15**	**13.09**	**8.80**	**7.90**	**6.53**

T_1: Prilled urea (PU) broadcast@100 kg Nha^{-1} during sowing
T_2: PU placed in the side furrow@100 kg Nha^{-1} during sowing
T_3: PU placed between two rows@100 kg Nha^{-1} during sowing
T_4: PU & seed in the same furrow@100 kg Nha^{-1} during sowing
T_5: USG at 5 cm depth as basal@75 kg N ha^{-1}
T_6: USG placed at 5 cm depth at 10 DAS@75 kg Nha^{-1}
T_7: USG placed at 5 cm depth at 20 DAS@75 kg Nha^{-1}
T_8: USG placed at 5 cm depth at 30 DAS@75 kg Nha^{-1}
T_9: USG at 10cm depth as basal@75 kg Nha^{-1}
T_{10}: USG at 10cm depth at 10 DAS@75 kg Nha^{-1}
T_{11}: USG at 10 cm depth at 20 DAS@75 kg Nha^{-1}
T_{12}: USG at 10cm depth at 30 DAS@75 kg Nha^{-1}
T_{13}: USG placed at 15 cm depth as basa@75 kg Nha^{-1}l
T_{14}: USG placed at 15 cm depth at 10 DAS@75 kg Nha^{-1}
T_{15}: USG placed at 15 cm depth at 20 DAS@75 kg Nha^{-1}
T_{16}: USG placed at 15 cm depth at 30 DAS@75 kg Nha^{-1}

4.1.3 Effective tillers hill^{-1}

Number of effective tillers hill^{-1} was significantly influenced by the different treatments (Appendix V and Table 3). Treatment T_{11} (USG placed at 10 cm depth at 20 DAS) gave the maximum effective tillers hill^{-1} (6.67) at harvest. USG placed at 15 cm depth at 10 DAS (T_{14}), 10 cm depth at 10 DAS (T_{10}) and 30 DAS (T_{12}) gave statistically identical number of effective tillers hill^{-1} (6.20, 6.07 and 5.80) respectively. On the other hand, treatment T_1 (PU broadcast) observed the minimum effective tillers hill^{-1} of 3.13 and it was statistically identical with PU placed in the side furrow (T_2). Similar result was reported by Mattas *et al*. (2011) who found that the significantly increased of effective tillers by applying equal amount of urea at different growth stages.

4.1.4 Number of non effective tillers hill^{-1}

A significant variation was also observed by the effect of different placement of PU and USG in respect of number of non effective tillers hill^{-1} at harvest (Appendix V and Table 3). It was found that maximum non-effective tillers hill^{-1} (1.03) was recorded in treatment PU broadcasted (T_1). USG placed at 10 cm depth at 20 DAS (T_{11}) produced the minimum non effective tillers hill^{-1} (0.47).

Table 3. Effect of prilled urea and urea super management on number of effective and non effective tillers hill^{-1} of wheat at harvest

Treatments	Effective tillers hill^{-1}	Non effective tillers hill^{-1}
T_1	3.13 j	1.03 a
T_2	3.77 ij	0.90 b
T_3	4.47 f-i	0.87 bc
T_4	4.80 e-h	0.87 bc
T_5	4.20 hi	0.80 cd
T_6	4.97 d-h	0.70 ef
T_7	4.77 e-h	0.67 f
T_8	4.33 g-i	0.67 f
T_9	5.20 c-g	0.87 bc
T_{10}	6.07 a-c	0.77 de
T_{11}	6.67 a	0.47 g
T_{12}	5.80 a-d	0.67 f
T_{13}	5.63 b-e	0.83 b-d
T_{14}	6.20 ab	0.70 ef
T_{15}	5.27 c-f	0.83 b-d
T_{16}	4.73 e-h	0.90 b
$S\bar{x}$	**0.276**	**0.025**
CV (%)	**9.58**	**5.96**

T_1: Prilled urea (PU) broadcast@100 kg Nha^{-1} during sowing

T_2: PU placed in the side furrow@100 kg Nha^{-1} during sowing

T_3: PU placed between two rows@100 kg Nha^{-1} during sowing

T_4: PU & seed in the same furrow@100 kg Nha^{-1} during sowing

T_5: USG at 5 cm depth as basal@75 kg N ha^{-1}

T_6: USG placed at 5 cm depth at 10 DAS@75 kg Nha^{-1}

T_7: USG placed at 5 cm depth at 20 DAS@75 kg Nha^{-1}

T_8: USG placed at 5 cm depth at 30 DAS@75 kg Nha^{-1}

T_9: USG at 10cm depth as basal@75 kg Nha^{-1}

T_{10}: USG at 10cm depth at 10 DAS@75 kg Nha^{-1}

T_{11}: USG at 10 cm depth at 20 DAS@75 kg Nha^{-1}

T_{12}: USG at 10cm depth at 30 DAS@75 kg Nha^{-1}

T_{13}: USG placed at 15 cm depth as basa@75 kg Nha^{-1}l

T_{14}: USG placed at 15 cm depth at 10 DAS@75 kg Nha^{-1}

T_{15}: USG placed at 15 cm depth at 20 DAS@75 kg Nha^{-1}

T_{16}: USG placed at 15 cm depth at 30 DAS@75 kg Nha^{-1}

4.1.5 Dry weight of root

Dry weight of root at harvest significantly influenced due to the effect of different management of PU and USG at harvest (Appendix VI and Table 4). The highest root dry weight (0.57 g $plant^{-1}$) was obtained from treatments of T_{11}(USG was placed at 10 cm depth at 20 DAS @ 75 kg N ha^{-1}) and T_4 (Prilled Urea and seeds placed in same furrow @ 100 kg N ha^{-1}). It was also at par with USG placed at 10 cm depth at 10 DAS (T_{10}), USG placed at 15 cm depth as basal (T_{13}) , PU placed between two rows (T3), USG placed at 5 cm depth at 20 DAS (T_7), USG placed at 5 cm depth at 30 DAS (T_8), USG placed at 10 cm depth as basal (T_9), USG placed at 15 cm depth at 20 DAS (T_{15}) of 0.53 g $plant^{-1}$, USG placed at 5 cm depth at 10 DAS (T_6), USG placed at 15 cm depth at 10 DAS (T_{14}) , PU placed in the side furrow (T_2) and Urea Super Granule (USG) at 5 cm depth as basal (T_5). Minimum root dry weight (0.43 g $plant^{-1}$) was recorded from PU broadcast (T_1) which was similar to PU placed in the side furrow (T_2) , Urea Super Granule (USG) at 5 cm depth as basal (T_5) and USG placed at 15 cm depth at 30 DAS (T_{16}) .

4.1.6 Dry weight of shoot

A significant variation was also found by the application of PU and USG in respect of dry weight of plant at harvest (Appendix VI and Table 4). Dry weight of plant was higher (11.29 g $plant^{-1}$) in treatment T_{11} (USG placed at 10 cm depth at 20 DAS) which was statistically similar to T_{10} (11.01 g $plant^{-1}$), T_9 (10.80 g $plant^{-1}$), T_4 (10.44 g $plant^{-1}$) and T_8 (10.44 g $plant^{-1}$). Lower shoot dry weight (8.20 g $plant^{-1}$) was obtained from T_1 (PU broadcast) treatment and it was statistically similar with T_2 (8.42 g $plant^{-1}$) treatment.

4.1.7 Total dry matter (TDM)

Total dry matter weight was significantly affected by the application of PU and USG (Appendix VI and Table 4). Among the treatments, T_{11} (USG placed at 10 cm depth at 20 DAS) produced the higher total dry matter weight (11.86 g $plant^{-1}$) which was followed by T_{10} (11.56 g $plant^{-1}$), T_9 (11.33), T_4, (11.01 g $plant^{-1}$) T_8 (10.97 g $plant^{-1}$) and T_{12} (10.85 g $plant^{-1}$) treatments. The lowest shoot dry weight (8.63 g $plant^{-1}$) was recorded in T_1 (PU was broadcasted @ 100 kg N ha^{-1} during sowing) and it was statistically identical with T_2 (8.93 g $plant^{-1}$) treatment. Das (1989) reported that the dry mater yield of rice was higher in deep placement of USG. Vijaya and Subbaiah (1997) showed that dry matter production of rice increased with the increasing urea super granules size when deeply placed.

Table 4. Effect of prilled urea and urea super granule management on dry weight of root, shoot and tatal dry matter of wheat at harvest

Treatments	Dry weight of root (g plant^{-1})	Dry weight of shoot (g/plant)	Total dry matter (TDM) (g/plant)
T_1	0.43 c	8.20 g	8.63 h
T_2	0.51 a-c	8.42 g	8.93 h
T_3	0.53 ab	9.67 d-f	10.19 c-g
T_4	0.57 a	10.44 a-d	11.01 a-d
T_5	0.49 a-c	10.00 c-e	10.48 b-f
T_6	0.52 ab	8.90 fg	9.39 f-h
T_7	0.53 ab	10.25 b-d	10.78 a-e
T_8	0.53 ab	10.44 a-d	10.97 a-d
T_9	0.53 ab	10.80 a-c	11.33 a-c
T_{10}	0.55 ab	11.01 ab	11.56 ab
T_{11}	0.57 a	11.29 a	11.86 a
T_{12}	0.57 a	10.28 b-d	10.85 a-d
T_{13}	0.55 ab	9.12 e-g	9.67 e-h
T_{14}	0.52 ab	8.71 fg	9.23 gh
T_{15}	0.53 ab	9.52 d-f	10.05 d-g
T_{16}	0.47 bc	9.99 c-e	10.46 b-f
$S\bar{x}$	**0.025**	**0.302**	**0.347**
CV (%)	**8.44**	**5.35**	**5.82**

T_1: Prilled urea (PU) broadcast@100 kg Nha^{-1} during sowing

T_2: PU placed in the side furrow@100 kg Nha^{-1} during sowing

T_3: PU placed between two rows@100 kg Nha^{-1} during sowing

T_4: PU & seed in the same furrow@100 kg Nha^{-1} during sowing

T_5: USG at 5 cm depth as basal@75 kg N ha^{-1}

T_6: USG placed at 5 cm depth at 10 DAS@75 kg Nha^{-1}

T_7: USG placed at 5 cm depth at 20 DAS@75 kg Nha^{-1}

T_8: USG placed at 5 cm depth at 30 DAS@75 kg Nha^{-1}

T_9: USG at 10cm depth as basal@75 kg Nha^{-1}

T_{10}: USG at 10cm depth at 10 DAS@75 kg Nha^{-1}

T_{11}: USG at 10 cm depth at 20 DAS@75 kg Nha^{-1}

T_{12}: USG at 10cm depth at 30 DAS@75 kg Nha^{-1}

T_{13}: USG placed at 15 cm depth as basa@75 kg Nha^{-1}l

T_{14}: USG placed at 15 cm depth at 10 DAS@75 kg Nha^{-1}

T_{15}: USG placed at 15 cm depth at 20 DAS@75 kg Nha^{-1}

T_{16}: USG placed at 15 cm depth at 30 DAS@75 kg Nha^{-1}

4.2 Effect of prilled urea and urea super granule managements on yield components of wheat

4.2.1 Length of spike

Length of spike differed significantly among the treatments was shown in Appendix VI and Table 5. Treatments T_{11} (USG placed at 10 cm depth at 20 DAS) gave the longest spike (24.13 cm) followed by T_{10} (USG placed at 10 cm depth at 10 DAS) of 23.88 cm and T_9 (USG placed at 10 cm depth as basal) treatments. The shortest spike (17.32 cm) was recorded in the treatment T_1 (PU broadcast) which was followed by T_{14} (19.43 cm), T_{13} (18.86 cm) T_{15} (18.71 cm), T_2 (18.48 cm) and T_{12} (18.18 cm) treatments.The result is also in agreement with the findings of Patel and Mishra (1994) who found significantly difference in panicle length from USG treatment over PU application.

4.2.2 Grains spike^{-1}

Number of total grains spike^{-1} showed significant variation due to the effect of different treatment of PU and USG (Appendix VI and Table 5). The maximum number of grains spike^{-1} was recorded (42.33) in treatment T_{11} (USG placed at 10 cm depth at 20 DAS) followed by T_{10} (41.67), T_7 (40.67), T_{12} (40.67), T_9 (40.33), T_{13} (40.00), T_4 (39.67) and T_{15} (39.67) treatments. On the other hand, treatment T_1 (PU broadcast) produced the minimum number of total grains spike^{-1} (37.00) followed by T_3 (38.00) , T_5 (38.33), T_{16} (38.33), T_2 (38.67), T_{14} (38.67), T_8 (39.00), T_6 (39.00), T_4 (39.67), T_{15} (39.67), T_9 (40.33), T_7 (40.67), T_{12} (40.67), T_{10} (41.67), and T_{11} (42.33) treatments.

4.2.3 Filled grains spike^{-1}

Number of filled grains spike^{-1} was significantly affected by the different treatments of PU and USG (Appendix VI and Table 5). The highest number of filled grains spike^{-1} (40.00) was obtained in T_{11} (USG placed at 10 cm depth at 20 DAS) and it was statistically identical with T_{10} (38.67), T_{12} (38.00), T_9 (37.33) and T_7 (37.00) treatments. The lowest number of filled grains spike^{-1} (32.67) was obtained from the treatment T_1 which was followed by T_3 (34.67), T_{14} (34.67) and T_2 (35.00) treatments.

4.2.4 Unfilled grains spike^{-1}

The unfilled grains spike^{-1} varied significantly due to the effect of different PU and USG treatments (Appendix VI and Table 5). Treatments T_1 (PU broadcast) and T_{14} (PU and seed in the same furrow) gave significantly maximum unfilled grains spike^{-1} (4.67 and 4.0, respectively). In contrast, treatment T_{11} (USG placed at 10 cm depth at 20 DAS) gave longest unfilled grains spike^{-1} followed by T_9 (USG placed at 10 cm depth as basal), T_{12} (USG placed at 10 cm depth at 30 DAS), T_5 (USG placed at 5 cm depth as basal), T_6 (USG placed at 5 cm depth at 10 DAS), T_{10} (USG placed at 10 cm depth at 10 DAS) and T_{16} (USG placed at 15 cm depth at 20 DAS) treatments. Thus result indicated that USG is a fertilizer that can be absorbed or uptake increasingly due to less loss of nitrogen from the soil that way lead to increase filled grains spike^{-1}.

Table 5. Effect of prilled urea and urea super granule management of Wheat on spike length, grains number, sterile and non sterile grains

Treatments	Length of spike (cm)	Grains spike^{-1} (No.)	Filled grains spike^{-1} (No.)	Unfilled grains spike^{-1} (No.)
T_1	17.32 f	37.00 d	32.67 d	4.67 a
T_2	18.48 ef	38.67 b-d	35.00 cd	3.67 bc
T_3	19.18 de	38.00 cd	34.67 cd	3.33 b-d
T_4	20.44 cd	39.67 a-d	36.33 bc	3.33 b-d
T_5	21.68 bc	38.33 cd	35.67 b-d	3.00 c-e
T_6	19.21 de	39.00 b-d	36.00 b-d	3.00 c-e
T_7	20.45 cd	40.67 a-c	37.00 a-c	3.67 bc
T_8	22.29 b	39.00 b-d	35.67 b-d	3.33 b-d
T_9	22.88 ab	40.33 a-c	37.33 a-c	2.67 de
T_{10}	23.38 ab	41.67 ab	38.67 ab	3.00 c-e
T_{11}	24.13 a	42.33 a	40.00 a	2.33 e
T_{12}	18.18 ef	40.67 a-c	38.00 a-c	2.67 de
T_{13}	18.86 d-f	40.00 a-d	36.67 bc	3.33 b-d
T_{14}	19.43 de	38.67 b-d	34.67 cd	4.00 ab
T_{15}	18.71 d-f	39.67 a-d	36.33 bc	3.33 b-d
T_{16}	19.59 de	38.33 cd	35.33 b-d	3.00 c-e
$S\bar{x}$	**0.562**	**0.926**	**1.008**	**0.269**
CV (%)	**4.80**	**4.06**	**14.28**	**4.82**

T_1: Prilled urea (PU) broadcast@100 kg Nha^{-1} during sowing
T_2: PU placed in the side furrow@100 kg Nha^{-1} during sowing
T_3: PU placed between two rows@100 kg Nha^{-1} during sowing
T_4: PU & seed in the same furrow@100 kg Nha^{-1} during sowing
T_5: USG at 5 cm depth as basal@75 kg N ha^{-1}
T_6: USG placed at 5 cm depth at 10 DAS@75 kg Nha^{-1}
T_7: USG placed at 5 cm depth at 20 DAS@75 kg Nha^{-1}
T_8: USG placed at 5 cm depth at 30 DAS@75 kg Nha^{-1}
T_9: USG at 10cm depth as basal@75 kg Nha^{-1}
T_{10}: USG at 10cm depth at 10 DAS@75 kg Nha^{-1}
T_{11}: USG at 10 cm depth at 20 DAS@75 kg Nha^{-1}
T_{12}: USG at 10cm depth at 30 DAS@75 kg Nha^{-1}
T_{13}: USG placed at 15 cm depth as basa@75 kg Nha^{-1}l
T_{14}: USG placed at 15 cm depth at 10 DAS@75 kg Nha^{-1}
T_{15}: USG placed at 15 cm depth at 20 DAS@75 kg Nha^{-1}
T_{16}: USG placed at 15 cm depth at 30 DAS@75 kg Nha^{-1}

4.2.5 Weight of 1000 grains (g)

Effect of PU and USG treatments showed significant difference in respect of weight of 1000-grains (Appendix VII and Table 6). The highest 1000-grain weight (40.11 g) was recorded in T_{11} (USG placed at 10 cm depth at 20 DAS) treatment which was statistically at par with T_{10} (39.55 g), T_7 (39.19 g), T_{12} (39.04), T_9 (37.76), T_{13} (37.68 g), T_{14} (37.25 g) and T_6 (37.20 g) treatments. The lowest 1000-grain weight (32.84 g) was observed in T_4 (PU & seed in the same furrow) and it was statistically similar with T_1 (32.89 g), T_{16} (34.32 g), T_2 (34.52 g), T_5 (34.86 g), T_{15} (34.99 g) and T_8 (35.84 g). Sen and Pandey (1990) also found similar results on 1000-grain weight using USG at 5, 10 and 15 cm depth of placement.

4.2.6 Grain yield

A significant variation was observed in respect of grain yield due to the effect of different PU and USG treatments (Appendix VII and Table 6). Among the treatment, significantly the highest grain yield (4.0 t ha^{-1}) was recorded in T_{11} (USG placed at 10 cm depth at 20 DAS) treatment and it was statistically identical with T_{10} (3.80 t ha^{-1}), T_6 (3.73 t ha^{-1}) and T_9 (3.69 t ha^{-1}) treatments. The lowest grain yield (2.90 t ha^{-1}) was recorded from T_1 (PU broadcast) at par with T_4 (3.10 t ha^{-1}), T_2 (3.19 t ha^{-1}), T_{12} (3.28 t ha^{-1}), T_7 (3.29 t ha^{-1}) and T_{16} (3.29 t ha^{-1}) treatments. The highest yield was obtained from T_{11}, T_{10}, T_6, T_9 treatments might be due to the production of higher effective tiller, filled grains and 1000 grain weight. It can be assumed from the better performance of USG that N loss from this fertilizer was remarkably less than that of PU. Similar results have been reported by Mishra et al.,(1999). Treatments T_{11}, T_{10}, T_9, T_6 gave 38, 31, 27 and 29% higher yield than that of T_1 treatment respectively Khalil *et al.* (2006). Similar results were also obtained by Ameta and Singh (1990) who reported that placement of 75 kg USG at 8-10 cm soil depth, 7 days after transplanting produced higher grain yield. Singh and Mahaptra (1989) also found similar results. Patel and Desai (1987) also reported that the applying N at the rate of 58 kg ha^{-1} as urea super granules placed at 10-12 cm depth gave the higher yield (4.38 t ha^{-1}).

4.2.7 Straw yield

PU and USG treatments exerted significantly influence on straw yield (Appendix VII and Table 6). The highest straw yield (5.31 t ha^{-1}) was obtained from treatment T_{11} (USG placed at 10 cm depth at 20 DAS) which was statistically similar with T_{10} (5.23 t ha^{-1}), T_{15} (5.17 t ha^{-1}), T_8 (5.14 t ha^{-1}), T_{16} (5.14 t ha^{-1}), T_{13} (5.13 t ha^{-1}) T_9 (5.02 t ha^{-1}), T_6 (4.95 t ha^{-1}), T_{12} (4.95 t ha^{-1}), T_7 (4.92 t ha^{-1}) and T_3 (4.89 t ha^{-1}) treatments. Treatment T_1 (PU broadcast) gave the lowest straw yield (4.50 t ha^{-1}) which was at par with T_2 (4.59 t ha^{-1}), T_5 (4.63 t ha^{-1}), T_4 (4.64 t ha^{-1}), T_{14} (4.71 t ha^{-1}) and T_3 (4.89 t ha^{-1}) treatments. Rao *et al.* (1986) reported that the 80 kg N ha^{-1} on rice field as USG placed at 8-10 cm depth in between the hills, gave higher straw yield compared to PU. Similar results were also observed on straw yield of rice by Swain *et al*. (1995).

4.2.8 Biological yield

Biological yield differed significantly among the effect of different management of PU and USG (Appendix VII and Table 6). Among the treatment, the higher biological yield (9.31 t ha^{-1}) was noticed in treatment T_{11} (USG placed at 10 cm depth at 20 DAS) which was statistically identifical with T_{10} (USG placed at 10 cm depth at 10 DAS) (9.03 t ha^{-1}), T_9 (8.72 t ha^{-1}), T_6 (8.71 t ha^{-1}), T_{15} (8.70 t ha^{-1}), T_8 (8.64 t ha^{-1}), T_{13} (8.51 t ha^{-1}), T_3 (8.43 t ha^{-1}) and T_{16} (8.43 t ha^{-1}) treatments. The lowest biological yield (7.43 t ha^{-1}) was found in T_1 (PU broadcast) and at per with T_4 (7.73 t ha^{-1}), T_2 (7.78 t ha^{-1}), T_5 (8.10 t ha^{-1}), T_7 (8.21 t ha^{-1}), T_{14} (8.20 t ha^{-1}), T_2 (7.78 t ha^{-1}) and T_{12} (8.23 t ha^{-1}) treatments.

Table 6. Effect of prilled urea and urea super granule management on yield and yield contributing characters of wheat

Treatments	1000-grains weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	32.89 f	2.90 f	4.50 d	7.43 e	39.43 bc
T_2	34.52 d-f	3.19 d-f	4.59 cd	7.78 c-e	40.96 bc
T_3	36.19 b-e	3.53 b-d	4.89 a-d	8.43 a-d	41.93 a-c
T_4	32.84 f	3.10 ef	4.64 b-d	7.73 de	40.04 bc
T_5	34.86 c-f	3.48 b-e	4.63 b-d	8.10 b-e	42.90 ab
T_6	37.20 a-e	3.73 a-c	4.98 a-c	8.71 a-c	45.45 a
T_7	39.19 ab	3.29 d-f	4.92 a-c	8.21 b-e	40.06 bc
T_8	35.84 c-f	3.50 b-d	5.14 a	8.64 a-d	40.49 bc
T_9	37.76 a-c	3.69 a-c	5.02 ab	8.72 a-c	42.37 a-c
T_{10}	39.55 a	3.80 ab	5.23 a	9.03 ab	42.08 a-c
T_{11}	40.11 a	4.00 a	5.31 a	9.31 a	42.93 ab
T_{12}	39.04 ab	3.28 d-f	4.95 a-c	8.23 b-e	39.82 bc
T_{13}	37.68 a-d	3.38 c-e	5.13 a	8.51 a-d	39.72 bc
T_{14}	37.25 a-e	3.49 b-d	4.71 b-d	8.20 b-e	42.55 a-c
T_{15}	34.99 c-f	3.53 b-d	5.17 a	8.70 a-d	40.55 bc
T_{16}	34.32 ef	3.29 d-f	5.14 a	8.43 a-d	39.00 c
$S\bar{x}$	**0.9576**	**0.1155**	**0.1238**	**0.2858**	**1.099**
CV (%)	**4.54**	**5.79**	**4.36**	**5.90**	**4.61**

T_1: Prilled urea (PU) broadcast@100 kg Nha^{-1} during sowing

T_2: PU placed in the side furrow@100 kg Nha^{-1} during sowing

T_3: PU placed between two rows@100 kg Nha^{-1} during sowing

T_4: PU & seed in the same furrow@100 kg Nha^{-1} during sowing

T_5: USG at 5 cm depth as basal@75 kg N ha^{-1}

T_6: USG placed at 5 cm depth at 10 DAS@75 kg Nha^{-1}

T_7: USG placed at 5 cm depth at 20 DAS@75 kg Nha^{-1}

T_8: USG placed at 5 cm depth at 30 DAS@75 kg Nha^{-1}

T_9: USG at 10cm depth as basal@75 kg Nha^{-1}

T_{10}: USG at 10cm depth at 10 DAS@75 kg Nha^{-1}

T_{11}: USG at 10 cm depth at 20 DAS@75 kg Nha^{-1}

T_{12}: USG at 10cm depth at 30 DAS@75 kg Nha^{-1}

T_{13}: USG placed at 15 cm depth as basa@75 kg Nha^{-1}l

T_{14}: USG placed at 15 cm depth at 10 DAS@75 kg Nha^{-1}

T_{15}: USG placed at 15 cm depth at 20 DAS@75 kg Nha^{-1}

T_{16}: USG placed at 15 cm depth at 30 DAS@75 kg Nha^{-1}

4.2.9 Harvest index

The data on harvest index indicated that the different sowing depth and time of PU and USG showed significant variation among treatments (Appendix VII and Table 6). T_6 treatment (5 cm sowing depth of USG at 10 DAS) having the maximum harvest index (45.45%) and it was statistically similar with T_{11} (42.93%), T_5 (42.90%), T_{14} (42.55%), T_9 (42.37%), T_{10} (42.08) and T_3 (41.93%) treatments. In contrast, the lowest harvest index (39.00%) was noticed in USG placed at 15 cm depth at 30 DAS T_{16} and it was at par with T_1 (39.43%), T_{13} (39.72%), T_{12} (39.82%), T_4 (40.04%), T_7 (40.06%), T_8 (40.49%), T_{15} (40.55%) and T_2 (40.96%) treatments. These results indicate that lower sowing depth and time gave the higher harvest index but higher depth and time of USG sowing gave the lower harvest index in case of more depth and higher duration of USG placement did not efficient for higher yield.

Chapter 5

Summary and conclusion

CHAPTER 5
SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy Farm, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka during the period from November 2010 to March 2011 to study on the effect of different placement methods and time of application of prilled urea (PU) and urea super granule (USG) on the growth, yield contributing characters and yield of irrigated wheat (var. Shatabdi). Sixteen treatment of nitrogen (prilled and super granule urea) *viz.* T_1= Prilled urea (PU) broadcasted @100 kg N ha^{-1} during sowing, T_2 = PU placed in the side furrow @100kg N ha^{-1} during sowing, T_3 = PU placed between two rows @100kg N ha^{-1} during sowing, T_4 = PU & seed in the same furrow @100kg N ha^{-1} during sowing, T_5 = Urea Super Granule (USG) at 5 cm depth as basal @ 75kg N ha^{-1}, T_6 = USG placed at 5 cm depth at 10 DAS @ 75kg N ha^{-1}, T_7 = USG placed at 5 cm depth at 20 DAS @ 75kg N ha^{-1}, T_8 = USG placed at 5 cm depth at 30 DAS @ 75kg N ha^{-1}, T_9 = USG placed at 10 cm depth as basal @ 75kg N ha^{-1}, T_{10} = USG placed at 10 cm depth at 10 DAS @ 75kg N ha^{-1}, T_{11} = USG placed at 10 cm depth at 20 DAS @ 75 kg N ha^{-1}, T_{12} = USG placed at 10 cm depth at 30 DAS @ 75 kg N ha^{-1}, T_{13} = USG placed at 15 cm depth as basal @ 75 kg N ha^{-1}, T_{14} = USG placed at 15 cm depth at 10 DAS @ 75kg N ha^{-1}, T_{15} = USG placed at 15 cm depth at 20 DAS @ 75kg N ha^{-1} and T_{16} = USG placed at 15 cm depth at 30 DAS @ 75 kg N ha^{-1} were included in the experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

The analysis of variance results regarding the morphological, yield and yield contributing characters of irrigated wheat under the application of PU and USG showed significant different where the plant height and number of total tillers $hill^{-1}$ data was recorded at 15 days interval from 30 DAS up to harvest. Morphological parameters, yield and yield contributing characters data were recorded at harvest. Among the growth parameters, the tallest plant (31.85, 47.61, 69.61, 88.06 and 97.73 cm) was observed in the treatments T_{11} (USG placed @10 cm depth at 20 DAS) irrespective of growth stages and treatment T_1 (PU broadcast) gave the shortest plant except 60 DAS. Treatment T_{11} also recorded the maximum production of tillers $hill^{-1}$ (2.03, 3.70, 5.93, 7.63 and 7.13) at 30, 45, 60, 75 and at harvest, respectively where production of tillers rapidly increased up to 75 DAS and than decreased. Application of PU as broadcast gave the lower production of tillers hill^{-1}. Significantly the maximum number of effective and non effective tillers hill^{-1} were also recorded (6.67 and 1.03) in T_{11} (USG placed @10 cm depth at 20 DAS) and T_1 (PU broadcast) treatment and the minimum (3.13 and 0.47) in the treatment T_1 and T_{11}, respectively. Treatment T_{11} also produced significantly the higher production of root (0.57 g plant^{-1}) and plant (11.29 g plant^{-1}) dry weight as well as total dry matter (11.86 g plant^{-1}) and T_1 gave the lower production on root (0.43g plant^{-1}), shoot (8.20 g plant $^{-1}$) and TDM (8.63 g plant^{-1}).

The longest spike (24.13 cm), maximum number of grains spike-^{1} (42.33) and filled grains spike^{-1} (40.00) were obtained from T_{11} treatment and the shortest spike (17.32 cm), minimum grains spike^{-1} (37.00) and minimum filled grains spike^{-1} (32.67) were recorded in T_1 treatment. Number of unfilled grains spike^{-1} was the maximum (4.67) and the minimum (2.33) in treatment T_1 and T_{11}, respectively. Thousand grain weight was also higher (40.11 g) in treatment T_{11} and lower (32.84 g) in treatment T_4 (PU & seed in the same furrow). The higher grain yield (4.00 t ha^{-1}), straw yield (5.31 t ha^{-1}) and biological yield (4.00 t ha^{-1}) were obtained from T_{11} treatments and T_1 gave the lower yields (2.90, 4.50 and 7.43 t ha^{-1}). However, harvest index was maximum (45.45%) in the treatment T_6 (USG placed @ 5 cm depth at 10 DAS) and lower in T_{16} (USG placed @15 cm depth at 30 DAS).

On the basis of the results, it can be concluded that Urea Super Granule had positive impact on wheat production under irrigated condition. Moreover, USG application may be a good option to minimize production cost as well as increase yield. Hence USG @ 75 kg N ha^{-1}to be placed at 10 cm depth after 20 days of sowing along with other fertilizers could be a way of increasing economic yield of irrigated wheat.

It is suggested to repeat the study at different locations of Bangladesh to come up with a final recommendation.

References

CHAPTER V
REFERENCES

Agarwal, S.K. and Sharma, S.D. (1992). Effect of sources of nitrogen on the production of rice (*Oryza sativa* L.). *Indian J. Agril. Res*., **26** (2): 71-76.

Ahmed, M. and Hossain, S. M. A. (1992) . Effect of seed rate, nitrogen fertilization and time of harvest on the seed yield of wheat. *Bangladesh Agron. J.* **4** (1&2): 35-43.

Ahmed, M.H., Islam, M.A., Kader, M.A. and Anwar, M.P. (2000). Evaluation of urea supre granules as source of nitrogen in transplant Aman rice. *Pakistan. J. Biol. Sci.*, **3** (5): 735-737.

Akhter, S. (1999). Effect of row-spacing and urea super granule on the yield and yield contributing characters of T. aman rice. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh. p. 33.

Alam, B.M.R. (2002). Effect ofdifferent level of urea super granules on growth and yield of three varieties of Boro rice. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh. p. 119.

Ali, M. (1985). Nitrogen fertilize efficiency in two major rice soils of Bangladesh. *Intl. Rice Res. Newsl.*, **10** (6): 23-24.

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

Ananda, N. (2004). Effect of zinc, iron and split application of nitrogen on growth, yield and quality of durum wheat (*Triticum durum* Def.). M. Sc. (Agri) Thesis, Univ. Agric. Sci., Dharwad.

Apparao, G. (1983). Efficiency of urea super granules (USG). *Seed and Farms.*, **9** (6): 50-51 [cited from rice abstr., **185** (4): 56].

Awasthi, U.D. and Bhan, S. (1993). Performance of wheat (*Triticum aestivum*) varieties with different levels of nitrogen in moisture-scarce condition. *Indian J. Agron.* **38** (2): 200-203.

Ayoub, A.T. (1999). Fertilizers and the environment. *Nutr. Cycling in Agroecosystems*, **55**: 17-121.

Ayoub, M., Civertin, S., Lussicr, S. and Smith, D. L. (1994). Timing and level of nitrogen fertility effects on spring wheat yield in Eastern Canada. *Crop Sci.* **34** (3): 748-789.

BARI (Bangladesh Agricultural Research Institute) (1997). Increase wheat cultivation and decrease irrigation cost (A folder in Bengali) Wheat Res. Centre. Bangladesh Agril. Res. Inst. Nashipur, Dinajpur. pp. 12-15.

BBS (Bangladesh Bureau of Statistics) (2011). Statistical Year Book of Bangladesh. Bangladesh Bur. Stat. Div. Min. Plan., Govt. Peoples Repub. Bangladesh, p. 37.

Bellido, L. L., Bellido, R. J. L., Castillo, J. F. and Bellido, F. J. L. (2000). Effect of tillage crop rotation and nitrogen fertilization on wheat under rainfed mediterranean conditions. *Agron. J.* **92** (2): 1056-1066.

Bhardwaj, A.K. and Singh, Y. (1993). Increasing nitrogen use efficiency through modified urea materials in flooded rice in molli. Soils. *Annals Agril. Res.*, **14** (4): 448-451.

Bhopal Singh and Singh, C. P. (1991). Effect of time of nitrogen application in wheat (*Triticum aestivum*) in northern condition. *Indian J. Agron.*, **36** (3): 326-328.

Bhuiyan, N.I., Miah, M.A.M. and Ishaque, M. (1998). Research on USG, findings and future research areas and recommendation. Paper presented at the National Workshop on urea super granules technology, held at BARC, Dhaka, Bangladesh, 25 June, 1998.

Biswas, P. K. (1987). A study on the relative merits of mixed cropping under two levels of irrigations. MS Thesis, Dept. Agron. Sher-e-Bangla Agric. Univ. Mymensingh. p. 38-40.

Bouwmeester, R. J. B., Vlek, P. L. G., Stumpe, J. M. (1985). Effect of environmental factors on ammonia volatilisation from a urea-fertilized soil. *Soil Sci. Soc. America. J*. **49**, 376–381.

Bowen, W.T., Diamand, R.B., Singh, U. and Thompson, T.P. (2005). Urea deep placement increases yield and saves N fertilizer in farmer's field in Bangladesh. Rice in life: scientific perspectives for the 21st century. *In: Proc.* World Rice Res. Conf., held in Tsukuba, Japan 4-7 November, 2004. pp. 369-372.

Chauhan, H.S. and Mishra, B. (1989). Fertilizer use efficiency of amended urea materials in flooded rice. *J. Agril. Sci.*, **112** (2): 227-821.

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.

Dash, A.K., Mishra, B.K., Jena, M.K. and Jena, D.(2003). Effect of dose and application methods of different ureas based fertilizers on yield of low land rice. *Annals Agril. Res.*, **24** (2): 308-313.

De Datta, S.K. and Buresh, R.J. (1989). Principles and practices of production. John Wiley and Sons. *Inc. Canada*. p. 350.

Deor, B.S. and Pathik, S. R. (1997). Response of late sown wheat (*Triticum aestivum*) as influenced by rate and time of nitrogen under rained conditions. *Indian J. Agron.*, **42** (3): 459-462.

Deshmukh, S. C., Rathore, A. S. and Sinha, N. K. (1994), *Efficiency of split application of nitrogen and phosphorus in irrigated wheat. Crop Res*., **83** (3): 493-498.

Dhane, S.S., Khadse, R.R., Patil, V.H. and Sauant, N.K. (1989). Effect of deep placed USG with limited green manures on transplanted rice yield. *Intl. Rice. Res. Newsl.*, **14** (4): 31.

Dhuka, A. K., Sadaria, S. G., Patel, J. C. and Patel, B.S.(1992) . Effect of rate and time of nitrogen application on late sown wheat. *Indian J. Agron*., **37** (2): 354-355.

Dhuka, A. K., Sadaria, S. G., Patel, J. C. and Vyas, M. N. (1991). Response of irrigated late sown wheat to nitrogen application. *Indian J. Agron.* **36** (2): 276-277.

Dighe, J. M., Upadhayaya, Y. M. and Sharma, N.K. (1994). Response of different wheat varieties to split application of N and P. *Crop Res*. **8** (1): 37-44.

Doygan, M.B. and Bongolan, F.F. (1985). Effect of different time intervals of application of nitrogen and phosphorus fertilizer on the yield of uplant rice in Zamboarga del sur Philippines. *J. Crop Sci.,* **10** (1): 5.

Dweivedi, R. K. and Bajpai, R. P. (1995). Effect of different sources of urea and nitrogen levels on low land rice. J. Res. *Birsa Agril. Univ,* **7**(2): 161-162 [Field Crop Abst. 49 (822, 1996].

FAO (Food and Agricultural Organization) (2006). Production Year Book. Food and Agriculture Organization, *Rome, Italy*. **41**: 116-117.

Gami, J. K., Parmar, M. T., Patel, J. C. and Malavia. (1986). Effect of rates and methods of nitrogen application on dwarf wheat. *Indian J. Agron.*, **31** (4): 401-402.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Edn. John Willey and Sons, *New York. pp*. 97-411.

Halvorson, A. D., Black, A. L., Krupinsky, J. M., Merrill, S. D. Sicnhold, B. J. and Tanaka, D. L. (2000). Spring wheat response to tillage system and nitrogen fertilization with crop fallow system. *Agron. J.* **92**(2): 288-294.

Hasan, S.M. (2007). Effect of level of urea super granules on the performance of T. aman rice. MS Thesis, Department of Agronomy, *Bangladesh Agricultural University, Mymensingh*. pp. 4-23.

Hussain, M.J., Ali, M.Y., Rahman, M.A., Quayyum, M.A. and Choudury, D.A. (2010). Effect of urea super granule on the performance of cabbage in young Jamuna and Brahmaputra floodplain soils of Tangail. *Bangladesh J. Agril. Res*. **35**(2): 267-272.

IFDC.(International Fertilizer Development Center) (2007). Bangladesh will dramatically expand technology that doubles efficiency of urea fertilizer use. *IFDC Rep*. **32(**4), 1–5.

Islam, M.S., Biswas. G.C., Karmoker, M.C. and Suem. M.A. (2012). Effect of urea super granule on growth and yield of wheat. J. Environ. *Sci. & Natural Resources,* **4**(2): 143-146.

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

Jee, R.C. and Mahapatra, A.K.I. (1989). Effect of time of 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 and efficient and economic source of N for wetland rice. *Intl. Rice Res. Newsl*., **17**(3): 16-17.

Kapoor, V., Singh, U., Patel, S. K., Magre, H., Shrivastsva, L. K., Mishra, V. N., Das, R. O., Samadhiya, V. K., Sanabria, J., and Diamond, R. (2008). Rice growth, grain yield, and floodwater dynamics as affected by nutrient placement and rate. *Agron. J.* **100**, 526–536.

Khalil, M.I., Schmidhalter, U. and Gutser, R. (2009a). Emissions of N_2O, NH_3 and CO_2 from a cambisol with two contrasting water regimes and urea granular sizes. *Communications in Soil Sci & Plant Analysis*., **40**: 1191-1213.

Khalil, M.I., Schmidhalter, U. and Gutser, R.(2009b). Effects of ureas and nitrification inhibitors added to urea on nitrous oxide emissions from a loess soil. J. *Plant Nutr. & Soil Sic.,* **172**: 651-660.

Khalil, M.I., Schmidhalter, U. and Inubushi, K. (2006). Fertilizer N Movement and Recovery by Spring Wheat with Urea Super Granules Point-Placed at Different Soil Depths. MS thesis, Technical Univ of Munich, Institute of Plant Nutrition, Dept of Plant Sciences, *Freising, Germany*. pp. 2-10

Khalil, M.I., Schmidhalter, U. Gutser, R. and Heuwinkel, H. (2011). Comparative efficacy of urea fertlization via supergranules versus prills on nitrogen distribution, yield response and nitrogen use efficiency of spring wheat. *J. Plant Nutr.,* **34**: 779-797.

Kulkami, R.V., Marathe, A.B., Ingavale, M.T. and Patil, A.P. (2005). Effect of nitrogen application through prilled urea and urea super granules on drilled rainfed rice. *Soils and Crops*. **15**(1): 102-104.

Kumar, A., Sharma, D. K. and Sharma, H. C. (1995). Response of (*Triticum aestivum*) to irrigation and nitrogen in sodic soils. *Indian J. Agron.* **40**(1): 38-42.

Kumar, A., Sharma, D. K. and Sharma, H. C. (1999). Response of (*Triticum aestivum*) to irrigation and nitrogen in sodic soils. *Indian J. Agron*. **40**(1): 38-42.

Kumar, V. J. F., Balasubramanian, M. and Jesudas, D. M. (1996). Application of different forms of urea for rice. *J.Indian Soc. Soil Sci.* **44**(2): 267-270.

Kumare, V., Shotriya, G.C. and Kaore, S.V. (1990). Scope of urea super granules for rice in India. *Fertilizer News.* **35**(7): 23-29.

Malhi, S.S. and Nyborg, M. (1992). Influence of various factors on the relative effectiveness of fall-versus spring-applied N. In: proc. Intl. Symposium on Nutri. Management for Sustained Productivity, ed. M.S. Bajwa. Ludhiana, *India: Punjab Agril. Univ.,* pp. 355-365.

Malik, C. V. S. (1981). Response of wheat varieties to different levels of nitrogen. *Indian J. Agron*. **26**(1): 93-94.

Mattas, K.K., Uppal, R.S. and Singh, R.P. (2011). Effect of varieties and nitrogen management on the growth, yield and nitrogen uptake of durum wheat. *Res. J. Agril. Sci.,* **2** (2): 376-380.

Miah, M.N.H., Sudarshan, T., Sarker, M.A.R. and Ansari, T.H. (2004). Effect of number of seedling per hill and urea super granules on growth and yield of rice cv. BINAdhan 4. *J. Biol. Sci.,* **4**(2): 122-129.

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

Mishra, B.K., Das, A.K., Jena, D. and Swin, S.K. (1999a). Evaluation of placement methods for urea super granules in wet land rice (*Oryza sativa*) soil. *Indian J. Agron.,* **44**(4): 710-416.

Mishra, B.K., Mishra, s., Dash, A.K. and Jena, D. (1999b). Effect of time for urea super granules (USG) placement on low land rice. *Annals of Agril.Res.,* **20**(4): 443-447.

Mohanty, S.K., Chakravorti, S.P. and Bhadrachalam, A. (1989). Nitrogen balances studies in rice using 15 N-labeled urea super granules. *J. Agric. Sci.,* **113**(1): 119-121.

Nyborg, M. and Malhi, S.S. (1992). Effectiveness of fall-versus spring-applied urea on barley- pellet size and depth of placement. *Fertilizer Res.,* **31**: 235-239.

Pasha, A. (2005). Effect of split application of nitrogen and sulphur fertilization on growth, yield and quality of wheat. M.Sc. (Agri), Univ. Agric. Sci., Dharwad.

Patel, J. R. (1999). Effect of levels and methods of nitrogen application on wheat yield. *J. Maharashtra Agric. Univ*., **24** (1): 108-109.

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

Patel, N. M., Sadaria, S. G., Kaneria, B. B. and Khanpara, V.D. (1995). Effect of nitrogen, potassium and zinc on growth and yield of wheat. *Indian J. Agron*. **40**(2): 290-292.

Patel, N.M., Sadaria, S.G., Kaneria, B.B. and Khanpara, V.D. (1995). Effect of nitrogen, potassium and zinc on growth and yield of wheat. *Indian J. Agron.* **40**(2): 290-292.

Patel, R. M. and Upadhyay, P. N. (1993). Response of wheat (*Triticum aestivum*) to irrigation under varying levels of nitrogen and phosphorus. *Indian J. Agron.* **38**(1): 113-115.

Patel, S.R. and Mishra, V.N. (1994). Effect of different forms of urea and levels of nitrogen on the yield and nitrogen uptake of rice. *Adv. Plant Sic.,* **7**(2): 297-401.

Patra, S. S. (1990). Response of wheat varieties to fertilizer and irrigation. *Indian J. Agron*. **35**(3): 302-303.

Rahman, M.M. (2007). Effect of cultivar, depth of transplanting and depth of placement of urea supre granules on growth and yield or boro rice. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh. p. 94.

Rajput, R. L. and Verma, O. P. (1994). Effect of split and modified source of urea on the yield of irrigated wheat (*Triticum aestivum* L.). *Indian J. Agron.*, **39**(3): 403-405.

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

Ramaswamy, S., Sivasubramanian, V. and Sankaram, S. (1985). Effect of split applied N on rice yields. *Intl.Rice Res. Newsl.,* **16**(6): 25.

Rambabu, P., Pillai,K.G. and Reddy, S.N. (1983). Effect of modified urea materials and their methods of application on dry matter production, grain yield and nitrogen in rice.Oryza., **20**(2/3): 86-90.

Rao, R.V., Satyanarayana, V. and Reddy, G.H.S. (1986). Studied on the effect of time of nitrogen application on growth and yield of direct seeded sorna rice under puddle condition. *Andhra Agric. J.,* **24**(5): 181-186.

Reddy, P.S. and Reddy, G.V. (1989). Response of short duration rice to different forms of urea under puddle condition. Oryza, **26**(4): 399-402 [field crops abstr., **44**(1): 23, 1991].

Rekhi, R.S., Bajwa, M.S. and Starr, J.L. (1989). Response of short duration rice to different forms of urea under puddlecondition.Oryza, **26**(4): 399-402.

Russell, D.F. (1986). MSTAT-C (Computer based data analysis software). Crop and Soil Science Department, Michigan State University, USA.

Sahu, S.K. and Mitra, G.N. (1989). Comparative efficiency of large granule(LGU) and prilled urea (PU) on wetland rice. *Fertilizers News*. **34**(2): 31-33 *Field crop abst.,* **43**(5): 228-229, 1990.

Samra, J.S. and Dhillon, S. S., (2002). Response of durum wheat (*Triticum durum* Def.) to rate and time of nitrogen application under irrigated conditions. *J. Res., Punjab Agric. Univ*., **39**: 46-49.

Sarder, N.A., Shamsuddin, A.M. and Khan, N.H. (1988). Yield and yield components of wetland rice under various sources and levels of nitrogen. *Philippine J. Crop Sci*., **13**(3): 155-158.

Sarena, P. and Jana, R. L. (2001). Effect of split and modified source of urea on the yield of irrigated wheat (*Triticum aestivum*). *Indian J. Agron.,* **139**: 403-405.

Sarker, M.M.R., Shaheb, M.R. and Nazrul, M.I. (2012). Urea super granule: a good source of nitrogen on growth yield and profitability of cabbage in sylhet. *J. Environ. Sci. & Natural Resources*, **5**(1): 295-299.

Sarker, R.K. and Bastia, D. (1991). Relative efficiency of slow release N-carriers in rain fed low land rice. *Indian Agric*., **35**(1): 39-44.

Satrusajang, A., Snitwong, P., Buresh, R.J. and Frisen, D.K. (1991). N_{15} and S_{35} balances for fertilizers applied to transplanted rain fed lowland rice. *Thailand Fertilized Res.*, **28**(1): 55-65.

Savant, N.K., and Stangel, P.J. (1990). Deep placement of urea supergranules in transplanted rice: *Principles and practices. Fertil. Res*. **25**, 1–83.

Savant, N.K. and Stangel, P.J. (1998). Urea briquettes containing diammonium phosphate: A potential NP fertilizer for transplanted rice. *Fertil. Res.* 51, 85–94.

Savant, N.K., Crasewer, E.T. and Diamond, R.B. (1983). Use of super granules for wetland rice. A review. Fert. News., **28**(8): 27-35 [field crop abstr., 1984, **43**(5): 136].

Sen, A. and Pandey, B.K. (1990). Effect on rice of placement depth of urea supre granules. *Intl. Rice Res. Newsl.*, **15**(4): 18-51.

Sen, A. Gulatin, J.M.L. and Mohanty, J.K. (1985). Effects of root zone placement of nitrogen as urea super granuleson the yield performance wetland rice. Oryza, **22**(1): 40-44 [field crop abstr., **40**(2): 121, 1987].

Siddika, N. (2007). Effect of nitrogen management with prilled urea, urea super granules and leaf color chart on the performance of transplant aman rice (cv. BRRI dhan 41). MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh. pp. 35-44.

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

Singh, B.K. and Pal, C.S. (1991). Effect of modified urea materials on yield and N uptake of rain fed low land rice in calcariones soil. *Indian J. Agron.*, **36**(Supplement): 236-238.

Singh, G., Singh, O.P., Yadav, R.A., Singh, R.S. and Singh, B.B. (1993). Effect of N source and levels of nitrogen on grain yield, yield contributes, N uptake, recovery and response by the deep water condition. *Crop Res. (Hisar),* **6**(2): 214-216.

Singh, I.C. and Mahaptra, I.C. (1989). Economices of fertilizer use. Marketing News., **5**(12): 1-17.

SRDI (Soil Resources Development Institute). (1991). Land and Soil Resource Utilization Guide: Mymensingh Sadar Thana, Mymensingh. (In Bangali,). SRDI, Ministry of Agricultural, Dhaka, Bangladesh. P. 3.

Stark, J. C. and Tindall, T. A. (1992) , Timing split application of nitrogen for irrigated hard red spring wheat. *J. Prod. Agric*., **5**: 221-226.

Swain, S., Goel, A.K. and Das, F.C. (1995). Evaluation of urea super granules application methods. Agricultural Mechanization in Asia (AMA). *Africa and Latin America.,* **26**(3): 24-28.

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

Tian Ji-chun, HU Rui-bo, Deng Zhi-ying and Wang Yan-Xun. (2007). The variation and stability analysis of wheat dough stability time, Agriculture Sciences in China, **6** (2): pp.143-149.

UNDP (United Nations Development Programme) and FAO (Food and Agricultural Organization). (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2. Agroecological Regions of Bangladesh. United Nations Development Programme and Food and Agriculture Organization. pp. 212-221.

Upadhyay, V. B. and Tiwari, J. P. (1996). Influence of nitrogen, seed rate and mulch on wheat (*Triticum aestivum*) varieties under late sown conditions. *Indian. J. Agron.* **41**(4): 562-565.

Vijaya, D. and Subbaiah, S.V. (1997). Effect of methods of application of granular forms of fertilizer on growth, nutrient uptake and yield of paddy. *Ann. Agril. Res.*, **18**(3): 361-364.

Wagan, M.R., Oad, F.C. and Nenwani. (2002). Wheat growth and yield contributing characters under various sources and schedules of nitrogenous fertilizer. *Pak. J. App. Sci.*, **2**(11): 1013-1015.

Appendices

APPENDICES

Appendix I. The general, physical and chemical properties of the experimental land

A. General properties of the soil

Constituents	Characteristics
Location	Field Laboratory, Department of Agronomy, SAU, Dhaka
Soil Tract	Madhupur
Land type	high land, fertile, well drained
General soil type	Slightly acidic in reaction with low organic matter content
Agro-ecological zone	AEZ-28 (Madhupur Tract)
Topography	Fairly level
Soil colour	Dark grey
Drainage	Moderate

B. Physical properties of the soil

Constituents	Results
Particle size analysis	
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Colour	Dark grey
Consistency	Grounder

C. Chemical composition of the initial soil (0-15 cm depth)

Constituents	Results
Soil pH	5.8
Organic matter (%)	1.30
Total nitrogen (%)	0.101
Available phosphorus (ppm)	27
Exchangeable potassium (me/100 g soil)	0.12

Methods of analysis

Texture	Hydrometer methods
pH	Ptentiometric method
Organic carbon	Walkely-Black method
Total N	Modified kjeldhal method
Soluble P	Olsen method ($NAHCO^3$)
Exchangeable K	Flame photometer method (Ammonium)

Source : Soil Resources Development Institute (SRDI), Dhaka.

Appendix II. Monthly air temperature, rainfall, relative humidity and sunshine hours during the growing season (November 2011 to March 2012)

Month	Year	*Air temperature (^{O}C)			**Rainfall (mm)	*Relative humidity (%)	** Sunshine (hrs)
		Maximum	Minimum	Average			
November	2009	29.63	16.67	23.51	00.00	83.10	265.8
December	2009	25.52	15.70	20.61	00.00	87.55	142.8
January	2010	24.92	13.46	19.19	Trace	86.16	160.4
February	2010	28.77	15.33	22.05	Trace	73.57	223.4
March	2010	30.93	18.95	24.94	18.1	75.16	202.1

* Monthly average and ** Monthly total
Source: Climate division, Abhawah Vhavan, Agargaon, Dhaka.

Appendix III. Mean square on plant height at different days after sowing

Source of variation	Degrees of freedom	Mean square for Plant height (cm) at different days after sowing (DAS)				
		30	45	60	75	harvest
Replication	2	80.002	133.087	641.847	691.894	691.787
Factor A	15	17.846**	18.002**	30.301**	20.731**	31.766**
Error	30	1.367	3.756	7.099	6.337	4.446

Appendix IV. Mean square on number of total tillers hill^{-1} at different DAS and number of effective and non effective tillers hill^{-1} at harvest

Source of variation	Degrees of freedom	Mean square for						
		No. of total tillers hill^{-1} at different days after sowing (DAS)					No. of effective tillers hill^{-1}	No. of non effective tillers hill^{-1}
		30	45	60	75	harvest		
Replication	2	1.934	8.556	18.906	24.919	4.195	14.722	0.184
Factor A	15	0.397**	0.840**	2.035**	2.321**	2.263**	2.610**	0.054**
Error	30	0.014	0.110	0.151	0.240	0.142	0.230	0.002

Appendix V. Mean square on dry matter and yield contributing characters at harvest

Source of variation	Degrees of freedom	Mean square for						
		Dry weight of root (g plant^{-1})	Dry weight of plant (g plant^{-1})	Total dry matter weight (g plant^{-1})	Length of spike (cm)	No. of grains spike^{-1}	No. of unfilled rains spike^{-1}	No. of filled grains spike^{-1}
Replication	2	0.019	3.290	4.049	13.059	468.063	0.396	478.938
Factor A	15	0.004*	2.609**	2.748**	12.335**	5.911**	0.943**	9.178**
Error	30	0.002	0.275	0.362	0.948	2.574	0.218	3.04

Appendix VI. Mean square on yield characteristics after harvest

Source of variation	Degrees of freedom	Mean square for				
		1000-grans weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	71.191	0.824	1.003	4.661	42.429
Factor A	15	16.119**	0.225**	0.193**	0.708**	8.818**
Error	30	2.751	0.040	0.046	0.245	3.625

*= significant at 5% level, **= significant at 1% level of probability and ns= non significant