EFFECT OF UREA SUPER GRANULE DEEP PLACEMENT ON RICE CULTIVATION IN THE TIDAL COASTAL AREA OF KHULNA REGION

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ABSTRACT

A field experiment was conducted during the period from July to December, 2011 at Prof. Purnendu Gain Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna to observe the effect of urea super granule deep placement on rice cultivation in the coastal area of Khulna region. There were seven treatments of different forms and doses of urea viz. without nitrogen (WN), recommended N as prilled urea (PU - 216 kg ha^{-1}), recommended N as urea super granules (USG - 216 kg ha^{-1}), 75% recommended N as USG (USG-162 kg ha^{-1}), 50% recommended N as USG (USG-108 kg ha^{-1}), 125% recommended N as PU (PU-270 kg ha^{-1}) and 125% recommended N as USG (USG-270 kg ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Urea super granules (USG) were placed manually at the depth of 8-10 cm in the middle of four hills in alternate rows at 8 days after transplanting and prilled urea (PU) (216 kg ha^{-1} and 270 kg ha^{-1}) was applied in three equal splits. The other fertilizers such as P, K, S and Zn were applied at recommended doses. The results revealed that different forms and doses of nitrogen significantly affected plant height (cm), number of effective tillers $hill^{-1}$, number of filled grains $panicle^{-1}$, 1000 grain weight (g) and grain yield (t ha^{-1}). Urea super granules (USG) @ 216 kg ha^{-1} produced the highest plant height (134.4 cm) at harvest, longest panicle (22.19 cm), highest number of filled grains $panicle^{-1}$ (100.8), highest 1000 grain weight (31.98 g) and as a result the highest grain yield (5.79 t ha^{-1}) but statistically identical grain yield (5.6 t ha^{-1}) was obtained when USG was applied only @ 108 kg ha^{-1} (50% recommended N) and 162 kg ha^{-1}(75% recommended N). The lowest grain yield and yield contributing characters were found from control treatment. The result showed that 50% reduction of N can be possible by using USG without significant yield loss.

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ABBREVIATIONS AND ACRONYMS

ANOVA	=	Analysis of variance
AEZ	=	Agro-ecological Zone
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
BRRI	=	Bangladesh Rice Research Institute
CGR	=	Crop Growth Rate
cm	=	Centimeter
cv	=	Cultivar
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
Fig.	=	Figure
g	=	Gram
ha^{-1}	=	Per hectare
IFDC	=	International Fertilizer Development Centre
i.e.	=	That is
m^2	=	Square meter
NS	=	Not Significant
PU	=	Prilled Urea
t	=	Ton
TDM	=	Total Dry Matter
UDP	=	Urea Deep Placement
USG	=	Urea Super Granule
viz.	=	Namely
@	=	At the rate of

CHAPTER 1

INTRODUCTION

Bangladesh is a small country with a large population. Her economy is agriculture-based, so the national economy and general welfare of the country is largely dependent on sound development of agriculture.

Thus agriculture production has assumed the highest priority in the national planning of Bangladesh for removing the food shortage as well as improving the living standard of people of this country. Ever increasing population of the country is creating more pressure on agriculture to produce more food.

Rice (*Oryza sativa L.*) is the second widely grown cereal in the world and it is the staple food for more than half of the world's population. Asia is the leading producer of rice and most Asians get 60% of their protein and calories from rice (Iqbal *et al.*, 2003). In Bangladesh, rice is the principal food crop as it alone constitutes about 95.2% of the total food grain (rice, wheat & maize) production of 32.88 million metric tons (BBS, 2010).

Agriculture in Bangladesh is characterized by intense crop production with the rice based cropping systems. About 80% of cropped area of this country is used for rice production and the average yield of rice in Bangladesh is 2.82 t ha^{-1} (BBS, 2010). The yield of rice in Bangladesh is much lower than world average. It is mainly due to lack of potential varieties and management practices (Islam *et al*, 2009).

Of the mineral elements, nitrogen is the most important. It is required in large amount and limits grain yield when in short supply (Kirk, 2000). Nitrogen fertilizer plays an important role regarding growth and yield of rice (Prasertsak and Fukai, 1997). The agronomic practices like fertilizer application, especially nitrogen highly influence the yield and other yield components. Nitrogen fertilizer also prolongs grain filling duration that favors accumulation of more photosynthets in the grain and hence, increases grain weight. Physiological basis of variation in the yield of rice is due to grain filling duration and grain growth (Jones *et al.*, 1979 and Sadeque, 1985). So, optimum level of nitrogen supply is required to get satisfactory yield.

Nitrogen often gets lost through the process of NH_3 volatilization, de-nitrification, leaching, and/or runoff because of fast releasing nature of prilled urea (PU) which is usually broadcasted in splits conventionally by farmers.(De Datta, 1978).

Broadcast application of urea have been shown to be highly inefficient with N losses approaching 60% - 70% of the N applied (De Datta and Buresh, 1989). Several reports indicate that N fertilizer use efficiency in rice is very low. The recovery of the applied N by the rice in Bangladesh is reported to be lower than in any other country (Miyoshi. 1991). The efficiency of N fertilizer in wetland culture is very low and about 25%-30% in rice. Deep placement of USG, on the other hand, can stop de-nitrification process and minimizes urea concentration in irrigation water, thus reduces nitrogen loss and improves nitrogen use efficiency by 20-25 percent for better grain production (Craswell and De Datta, 1980 and Pillai, 1981).

Uptake of deep-placed N is elongated by placing the USG at lower depths and away from the plant. Urea super granules (USG) dissolve slowly in the soil providing a steady supply of available nitrogen throughout the growing period of the crop. It increases absorption rate, improves soil health and ultimately increases rice yield (Savant *et al.* 1991). Deep placement of USG effectively increases N use efficiency (31.7%) compared to conventionally applied prilled urea (Jaiswal and Singh, 2001). Thus USG becomes a very good source of nitrogen for rice. Using USG to transplant *aman* rice in Bangladesh can offer a compelling example of effective approach to managing urea fertilizer that results only improving efficiency but also greater yield with less urea fertilizer. As the risk of ground water contamination with nitrate N is less, it thus environmentally safer.

Therefore, the slow releasing process of nitrogen through the application of USG will be the effective way to control N loss. It can save 35-40% cost of nitrogenous fertilizer for each season and also increase the yield by 20-25%, side by side, reduces the wastage and dissipation of nitrogen through leaching. (Craswell and De Datta, 1980 and Pillai, 1981).

In tidal wetland situation, where it is not possible to follow the recommended schedule of split application of urea and where the risk of losses of surface applied N exists, a good alternative may be the deep placement of USG for higher yield.

In the above circumstances, this study was undertaken with the following objectives:

- To observe the effect of different forms and doses of nitrogenous fertilizer on rice cultivation in the coastal areas of Khulna region.
- To find out appropriate dose of nitrogenous fertilizer for higher yield of rice.
- To evaluate the USG as a source of nitrogen in T. *aman* rice.
- To find out the optimum dose of USG for higher yield of T. *aman* rice.

CHAPTER 2

REVIEW OF LITERATURE

Rice plant requires nitrogen throughout the growing period. Matsushima (1965) pointed out that when rice plant is supplied with much nitrogen during its vegetative period, the plant requires little nitrogen during its generative period: but in general, the rice plant has two peak stages for nitrogen requirement, one at the vegetative period and the other at the reproductive period.

2.1 Importance of Nitrogen in Plant Nutrition

Nitrogen has traditionally been considered one of the most important plant nutrients. However, there are many observations in respect of significance of nitrogen fertilizers.

Nitrogen is the important nutrient, representing two-third or more of total nutrients consumption in Asia (Barker and Robert, 1985). Accordingly, the plant must absorb larger amount of nitrogen to produce higher grain yield (Murayama, 1979).

Nitrogen gas comprises about 78 percent of the earth's atmosphere. Growing plants, animals and microbial populations need a continual source of N. It is an essential component of the proteins that build cell material and plant tissue. In addition, it is necessary for the function of other essential biochemical agents, including chlorophyll (which makes photosynthesis possible), many enzymes (which help organisms carry out biochemical processes and assimilate nutrients), and nucleic acids such as DNA, RNA (which are involved in reproduction) (Rao *et al.,* 1986).

Just as too little N can cause problems, too much N can also cause problems. These problems can extend to plants, humans, animals, and the environment. For example, in plants, too much N can produce weak stems in grain crops which lead to lodging (BRRI, 1978).

2.2 Importance of Nitrogen in Relation to Rice Production

Plant characters may be influenced by different levels and time of N fertilization. In a low-response cultivar the related uptake of nutrients at later growth stages may be related to serious mutual shading of the lower leaves.

Rice plant solely depends upon soil and applied source of N for the growth and yield. N plays a key role in supporting plant activity and increasing rice yield (BRRI, 1997 and Behera, 1998).

The application of nitrogen fertilizer is essential to rice (Rao *et al.* 1980). So, it is clear that nitrogen fertilizer is crucially important for the maximization of rice yield. This chapter describes the importance of nitrogen as a plant nutrient and its effects on various agronomic characteristics on rice plants in respect of different forms and doses of nitrogen application.

Among the various nutrients, nitrogen has the strongest influence on the growth and yield of rice. Nitrogen is one of the major nutrients, which is required in adequate amount at early, mid tillering, panicle initiation and ripening stage for better grain development (Matsushima, 1976).

Adequate N fertilizer is required during the period immediately after transplanting of seedlings (Haque and Bhuiyan, 1980; De Datta, 1978).

Nitrogen is the most important limiting nutrient in rice production and has heavy system losses when applied as inorganic sources in puddle field (Fillery *et al.*, 1984).

Therefore, Agronomic management is highly important for the better yield in rice production. Among the management practices, soil fertilization, particularly N management is the most important. Many workers at home and abroad investigated the response of N on rice growth for its successful production (Sarker and Ghatak, 1988; Park, 1987).

2.3 Different Effects of Nitrogen

By considering the above discussion it is said that different growth characters of rice plant are greatly influenced by the nitrogen application. The effects of nitrogen on physiological and agronomic behavior of rice plant are discussed below-

2.3.1 Effect of nitrogen on plant height

Plant height depends on fertilizer application, especially N-fertilizer. Hossain (1992) reported that plant height increases significantly with increasing of N-supply. Awan *et al.*, (1984) found that the higher dose of N application increased the plant height. Sing and Sharma (1987) also found the same result. Thakur (1991) obtained the highest plant height when 40%, 30% and 30% N were applied as basal, at maximum tillering and panicle initiation stages, respectively. Plant height increased with increasing rates of N application (Talukder. 1973). The higher levels of N (120kg ha^{-1}) significantly increased the plant height (Lenka and Behera. 1967)

Islam (1978) observed that S application along with urea-N, increased plant height. Similar report was given by Haque and Khan (1981).

2.3.2 Effect of nitrogen on number of tillers

Tillering is one of the most important developmental stages of rice, since it has a decisive bearing on grain yield. Tiller number is strongly correlated with grain yield, depending on the cultivars and crop environment.

Nitrogen fertilizer increases tillering and vegetative growth, increases plant height, grain and straw yield and number of heads usually proportionally to the amount of nitrogen added (Leonard *et al.*, 1976). Number of tillers $hill^{-1}$ increases with increasing nitrogen rates. Nitrogen application increased the number of tillers hill^{-1} (Jasim *et. al.*, 1984). Tillering of rice is strongly influenced by fertilizer (De Datta, 1981).

Tillering of rice plant is strongly influenced by nitrogen supply (BRRI, 1989). Tanaka (1983) observed in a typical tropical rice cultivar that N-content higher than 2.0% in the culm promoted tillering & lower than 0.8% favored the death of tillers. Finally tiller number hill^{-1} was a linear function of the maximum tiller at booting stage (Khanam. 1994). Lin and Lin (1983) raised two rice cultivars treated with 80, 120 and 160 kg N ha^{-1}. They found that high N levels resulted in the higher tiller number unit area^{-1}.

2.3.3. Effect of nitrogen on number of effective tillers

Nitrogen has a positive influence on the production of effective tillers per plant, yield and yield attributes (Jashim *et al.*, 1984; BRRI, 1990). Productive tillers hill^{-1}, grains panicle^{-1}, grain yield and straw yield significantly increased with increasing nitrogen fertilizer upto 150 kg N ha^{-1} but seed size had no significant difference between the nitrogen fertilizer rates (Rao *et al.*, 1980). Dixit and Singh (1979) observed that increased nitrogen application increased the productive tillers per plant.

2.3.4. Effect of nitrogen on leaf area

Leaf area is an important index used to study plant growth, assimilation and transpiration as related to utilization of solar radiation. At the optimum LAI the photosynthesis of the lowest leaves is equal only to their respiration. With an increase in LAI the light intensity becomes lower and even below the light compensation point at the basal part of the canopy and results in a negative contribution by lower leaves to total dry matter production (Gupta, 1990). In agronomic practices nitrogen application is one of the major factors influencing leaf area growth under most conditions. Nitrogen application affects average leaf size, number of leaves $shoot^{-1}$ and number of shoots $hill^{-1}$. The increase in LAI is caused by increase in number of tillers and in size of successive leaves. Nitrogen increases LAI or weight of leaf blades and this effect is greatest before panicle initiation (Murayama, 1979).

2.3.5. Effect of nitrogen on dry matter accumulation

Dry weight of rice plant is an important character for the vegetative dragness and growth forecast of this plant (Kusuda, 1993). There are many reports on the increase in total dry matter due to increased fertilizer application, particularly N (Park, 1987). Fertilization of crop with the higher rate of nitrogen (120 kg ha^{-1}) was found superior to the lower rate (80 kg ha^{-1}) in dry matter production (Mehrotra and Singh, 1982. Excess dry matter gives higher dry weight around heading simultaneously becomes low, causing a yield decline due to reduced ripening percentage. This situation is often referred to as overgrowth. The varieties which had high DM weight also had high leaf area. Leaf area is positively correlated with total DM (Anonymous, 1988).

2.3.6. Effect of nitrogen on panicle length

Singh and Sharma (1987) found that plant height, panicle number $hill^{-1}$, panicle length, straw yield and grain yield increased with increasing nitrogen doses. Similar result was obtained by Kehinde and Fagade (1987).

Increasing N up to 35 kg ha^{-1} increased grain yield mainly through increasing panicle length and number of filled grains $panicle^{-1}$ reported by Kuo (1971).

Dixit and Singh (1979) found that the increased nitrogen application increased the panicle length.

2.3.7. Effect of nitrogen on number of filled grains

Plants also need nitrogen at the reproductive and ripening stages for optimum number of spikelets panicle^{-1} and percentage of filled spikelets. Maurya and Yadav (1987) observed that plant height, panicle number m^{-2}, filled spikelets panicle^{-1} and grain yield increased with increasing nitrogen fertilizer doses. There was almost a liner response of grain yield to applied nitrogen. Panicle number m^{-2}, spikelets panicle^{-1}, filled spikelets panicle^{-1}and grain yield were in linear response to nitrogen application.

Thakur (1991a) reported that total grains panicle^{-1} was the highest when 40%, 30% and 30% N was applied as basal, at maximum tillering and panicle initiation stages, respectively.

Filled spikelet's are an important yield contributing factor and it is highly affected by such factors as climate, soil, variety and nitrogen application (Yoshida and Parao, 1976).

2.3.8. Effect of nitrogen on 1000-grain weight

Islam *et al.* (1990) reported that there was an increasing trend of 1000-grain weight with an increase in levels of nitrogen up to 80 kg ha^{-1}. A high nitrogen supply is reported to decrease the 1000 grain weight.

Awan *et al.* (1984) found that 1000-grain weight increased by the application of higher dose of nitrogen fertilizer.

Mondal *et al.* (1987) observed that increasing rates of N from 40 to 160 kg ha^{-1} increased the 1000-grain weight.

Nair and Gupta (1981) reported that sulphur application along with urea-nitrogen increased 1000-grain weight.

2.3.9. Effect of nitrogen on grain and straw yield

Bhattachoryya (1981) reported that the grain yield showed positive correlations with number of grains panicle^{-1} and number of spikelet panicle^{-1}.

A considerable amount of research indicated the positive response of rice to nitrogen fertilization (Pandey and Sinha, 1971). In general, grain yield increases with nitrogen addition up to a certain level.

Dixit and Singh (1979) showed that 80 kg N ha^{-1} increased rice yield from 2.18 t ha^{-1} to 4.19 t ha^{-1}. Higher doses of N produced higher amount of straw and grain (Awan *et al.*, 1984: Srivastava *et al.*, 1987).

Grain yield increases with increasing nitrogen fertilizer up to a level and then decreased (Singh and Pillai, 1991).

N application time and number of splitting may have efffect on grain yield. Wagh and Throat (1988) reported that 50+30+10+10 kg N ha^{-1} applied at 8 days after transplanting, maximum tillering, primordial initiation and flowering gave the highest yield.

Number of splitting of urea-N may have effect on grain yield. Milam *et al.* (1986) observed that 3 split applications of urea yielded higher than pre-plant incorporation.

2.3.10. Effect of nitrogen on biological yield and harvest index

Park (1987) observed that high N rates tended to increase biological yield and decrease harvest index.

Prasad (1981) found that the increasing rates of N application from 0 to 100 and 200 kg ha^{-1} increased biological yield but decreased harvest index. Harvest index of rice tends to be lower as total dry matter production increases (Machlis *et al.*, 1972).

The harvest index is the ratio of the yield of grain to the biological yield. The harvest index is about 0.3 for traditional tall varieties and 0.5 for improved short varieties (Yoshida, 1981). The harvest index for rice is negatively correlated with plant height (Tanaka *el al.* 1966).

2.4 N Fertilizer and Lodging

Excess nitrogen application causes lodging which reduces the yield. The height of plant increases, the thickness of the culm decreases and leaves become heavier with increase in applied nitrogen. Consequently a higher nitrogen supply aggravates lodging. Lodging is known to reduce grain yield by interrupting water and nutrient translocation in the shoot (Hitaka and Kobayashi 1962, 1964).

Lodging becomes serious when it occurs before and during the heading of the rice plants. When rice plants lodge they lie flat on the ground with their panicles. This results in faulty fertilization of the rice flowers and leads to sterility or to the formation of partly filled grains. If plants lodge two weeks after heading the percentage of empty grains is reduced to 19% (Jenning and Sornchai, 1964).

Increased nitrogen application, which is essential for high yield cause elongation of the lower internodes and making the crop more susceptible to lodging. Early lodging of long, thin culms disturbs leaf arrangement, increases mutual shading, interrupts translocation of nutrients and photosynthates causes sterility and reduces yield. Short and thick culm resists lodging and reduces respiration loss from the Culm (Jenning *et al.*, 1979).

2.5 Nitrogen Fertilizer Use Efficiency

The term fertilizer efficiency or fertilizer use efficiency could be interpreted in various ways. Fertilizer use efficiency is the output of any crop per unit of fertilizer applied under a specific set of soil and climatic conditions (De Datta, 1978). Fertilizer N use efficiency in rice is therefore, the amount of grain yield per unit amount of added fertilizer nitrogen. De Datta *et al.*(1981) reported that the highest yield of 6.0 ton ha^{-1} with efficiency of 16 kg rice kg^{-1} N was obtained at IRRI by deep placement of super granule urea.

Barbar (1977) defined fertilizer efficiency as the increase in yield of harvest portion of the crop per unit amount of fertilizer nutrient applied. But the profitable rate of fertilizer application was the maximization of grain yields at lower fertilizer rates. The other approach to fertilizer efficiency was based on plant uptake the least amount of fertilizer needed to match plant use with maximum grain yield was the most efficient rate of fertilizer application (De Datta, 1978). According to Yoshida (1975) efficiency of utilization of grain production in tropical wetland rice is about 50-kg rice kg^{-1} N absorbed.

2.6 Factors Affecting Nitrogen Use Efficiency

The different factors determining fertilizer efficiency in rice at the farm level are soil, crop, cultivar, season, environmental factors, time of planting, water management, weed control, manipulation of plant density and plant geometry, cropping sequence forms, rates, time of application and proper placement methods of N-fertilizer. (De Datta, 1978) suggested that any fertilizer treatment which produces high concentration of N in the flood water will lead to low recovery of N by the crop due to NH_3 volatilization, nitrification as well as de-nitrification. Hanif (1980) reported that alternate flooding and drying resulted in a recovery of 12-28% N while continuous flooding resulted in N recovery ranging from 56-78%. Tejeda *et al.*, (1981) reported that efficiency of applied N was strongly correlated with the cation exchange capacity of the soil, p^H (positively), and organic matter (negatively). The lower recovery of applied nitrogen fertilizer by rice plants was considered to be due to the losses of N-fertilizer from the soil-plant system. The potential loss mechanisms were de-ntrification, ammonia volatilization, run off and leaching, although up to 25% of the fertilizer N may be withheld from the rice plant by biological immobilization in the soil (Craswell and Vlek, 1978).

2.7 Nitrogen Loss and Importance of Deep Placement of Nitrogenous Fertilizers

The low land puddle soils remain waterlogged during the entire growth period of the rice crop. The important change in the soil due to water logging condition is the conversion of the root zone of the soil from an aerobic to anaerobic environment due to depletion of O_2 in the soil profile. The flooded or water logged puddle soil develops 2 zones. The upper zone 1-10 mm thick receives O_2 periodically from fresh supplies of irrigation water turns brown in color called oxidized zone and reacts like un-flooded upland soil. The remaining lower portion of puddle soil without 0_2 is called reduced zone. Ammoniacal nitrogen fertilizers when applied in such a soil system get oxidized in nitrate form (NO_3^-) in the oxidized zone. This nitrate nitrogen in turn leaches down to the reduced zone and gets denitrified to gaseous nitrogen. (Prasad, 1996).

In a laboratory study Prasad and Lakhdive (1969) showed that, about 80% of applied NO_3-N was lost in 72 hours due to de-nitrification. However, this loss of nitrogen can be prevented by incorporating ammoniacal nitrogen in to the reduced zone of the soil or in the form of deep placement. So, deep placement of nitrogen fertilizer in the form of USG should be done. Ammonia volatilization can be almost prevented by deep placement of nitrogen fertilizer (Prakasa Rao and Bhat, 1984).

Thomas and Prasad (1982) commented that, deep placement of nitrogen is important especially in rice, because placement in the reduced zone can prevent or at least retard the formation of nitrates and their subsequent loss by de-nitrification (Appendix 4).

2.8 Deep Placement and USG

An innovative yet simple technology that increases nitrogen use efficiency and which is being widely disseminated for managing urea in flooded rice systems in Bangladesh, involves the deep placement of USG (Urea Super Granules) in to the puddle soil shortly after transplanting rice.

USG may be of different sizes as spherical or pillow shaped with broken edges. The size of the pellet is 0.9-2.7 gm.

Within a week after transplanting rice USG are inserted in to the puddle soil by hand, being placed to a depth 7-10 cm in the middle of alternating squares of 4 hills of rice. In the same line the next centre of 4 hills should be left without application of USG but the next of it should be applied. In this way alternatively the USG are applied (Islam and Dey, 2007).

2.9 Effect of Deep Placement of USG on Different Growth and Yield Attributes of Rice

2.9.1 Effect on plant height

Rahman (2006) found that effect of depth of placement of USG was significant on all growth characters and the yield attributes except plant height.

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

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 increase of urea super granule size and were greater with the deep placement method of application both N and P compared with broadcasting.

Mishra *et al.* (1999) 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, further treatments were compared with split application of 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.

Sahu *et al.* (1991) reported that the effects of N source, rate and application method on rice in the 1982 monsoon season (cv. CR 1009) and in 1982/83 winter season (cv. IR 36). Yields were increased by N, but urea supper granules gave higher yields than PU particularly in the monsoon season. Yields were higher when USG was placed midway between every alternate 4 hills than from broadcasting and again were higher when N was given in 3 split applications (transplanting + maximum tillering + panicle initiation) than at the transplanting.

2.9.2 Effect on number of tillers

Hasan (2007) conducted an experiment during the *aman* season of 2006 and recorded the increased number of tillers $hill^{-1}$with increased nitrogen level as USG.

Alam (2002) observed that total tillers $hill^{-1}$and effective tillers $hill^{-1}$were increased significantly with the increase of level of USG, when USG was applied as one, two, three and four granules per 4 hills during the *boro* season. Jee and Mahapatra (1989) also observed that number of panicles m^{-2}were significantly higher when USG was applied at 90kg ha^{-1}as deep placement than split application of urea.

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

Rama *et al.* (1989) mentioned that the number of panicles m^{-2} increased significantly when nitrogen level increased from 40 to 120 kg N ha^{-1} as different modified urea materials. Urea super granules produced significantly higher number of panicles m^{-2} and grains $panicle^{-1}$ and ultimately the highest number of tillers was produced than the application of PU.

Jee and Mahapatra (1989) observed that number of panicles m^{-2} were significantly higher at the rate of 90 kg N ha^{-1} as deep placed USG than split application of PU.

Almost similar results were also found by Singh and Singh (1986). They reported that number of tillers m^{-2} increased with increasing nitrogen fertilizer. The number of tillers m^{-2} was significantly higher in USG than PU in all levels of nitrogen.

2.9.3 Effect on panicle length

Sen and Pandy (1990) reported that the application of USG at the rate of 38.32 kg

N ha $^{-1}$ gave higher yield than broadcast PU and there were no difference in panicle length.

Sarder *et al.* (1988) carried out an experiment in wetland rice that was given PU, USG and SCU at the rate of 23.7, and 94.8 kg N ha^{-1}. They applied urea as broadcast in 3 splits. Urea super granules as point placement at transplanting and sulphur coated urea as broadcast and incorporated at transplanting. They showed that USG only at the highest N rates gave greater plant height, panicle length and total number of grains panicle^{-1} than those of other N sources.

2.9.4 Effect on grains panicle^{-1}

Surendra *et al.* (1995) conducted an experiment during *rainy* season with nitrogen level @ 0, 40, 80, 120 kg ha^{-1} and sources of nitrogen, USG and urea dicyandiamide @ 80 kg ha^{-1}. They showed that USG and urea dicyandiamide produced significantly higher number of filled grains panicle^{-1}, 1000 grain weight and grain yield than PU @ 80 kg N ha^{-1}.

Rama *et al.* (1989) observed that the number of grains panicle^{-1} was significantly higher at the rate of 40, 80 or 120 kg N ha^{-1} as USG at deep placed than split application of urea.

2.9.5 Effect on 1000- grain weight

Hasan (2007) showed that different levels of USG did not have any significant effect on 1000-grain weight of three *aman* rice cultivars. Rama *et al.* (1989) observed that the number of grains panicle^{-1} was significantly higher at the rate of 40, 80 or 120 kg N ha^{-1} as USG at deep placed than split application of urea. They have observed that spikelet's panicle^{-1}, percent sterility and 1000-grain weight did not differ significantly due to different modified urea materials viz. PU, USG and SCU.

Alam (2002) conducted an experiment at the Agronomy Field Laboratory, BAU, Mymensingh during the *boro* season with three varieties and four levels of USG. He observed that 1000-grain weight was not influenced by level of USG.

Thakur (1991 b) observed that yield attributes and yield differed significantly due to levels and sources of nitrogen at 60 kg N ha^{-1}. Urea super granule had produced the highest number of panicle unit^{-1} area, panicle weight, number of grains panicle^{-1}, 1000 grain weight and ultimately gave the highest grain yield of 4.77 t ha^{-1} in 1987 and 4.94 t ha^{-1} in 1988.

Rahman (2003) showed that different level of USG did not have any significant effect on 1000-grain weight of two *aman* rice cultivars.

2.9.6 Effect on grain and straw yield

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 to be the highest (5.20 and 7.45 ton ha^{-1}, respectively) from the level of USG @ 3 pellets 4 hill^{-1} or 90 kg N ha^{-1} as USG. Singh and Kumar (1983) stated that grain yield was increased consistently with increasing N application up to 87 kg N ha^{-1}. The source of nitrogen was USG.

Dhane *et al.* (1989) stated that deep placement of urea super granules (USG) significantly increased grain and straw yields of rice. Singh *et al.* (1989) reported that placement of urea super granules at 10 cm depth resulted in maximum grain and straw yields (4.3 and 5.9 t ha^{-1} respectively).

Dwivedi and Bajpai (1995) conducted a field experiment during *rainy* season on rice cv. *Ruche,* which was given 0-90 kg N ha^{-1} as different forms of urea and they found that the grain yield was the highest with USG application and the lowest with urea spray application. Conversely, Apparao (1983) pointed out deep placement of 50 kg N ha^{-1} as USG got the indifferent significant yields of the paddy compared with urea applied basally or in 3 split applications.

Swain *et al.* (1995) evaluated the performance of USG application methods in low land transplanted rice. They have reported that USG gave higher grain and straw yield.

According to the field experiment of Hakim (1998) at the field of Bangladesh Institute of Nuclear Agriculture (BINA) during *aman* season including two forms of urea (PU and USG) at the rate of 80kg N ha^{-1} and four varieties. Deep placement of USG as nitrogen source gave significant higher grain (4.41 t ha^{-1}) than PU (3.81 t ha^{-1}) application.

Bowen *et al.* (2005) experimented 531 on-farm trials during the *boro* and *aman* seasons in 7 districts of Bangladesh from 2000-2004. The results showed that UDP (deep placement of urea super granules) increased grain yields by 1120 kg ha^{-1} and 890 kg ha^{-1} during the *boro* and *aman* seasons, respectively.

Sahu *et al.* (1991) worked on the method of application of USG in low land rice soil and showed that USG gave higher yields than PU when USG was placed at midway between every alternate 4 hills.

Jaiswal and Singh (2001) conducted an experiment with urea super granules and prilled urea both at 60 and 120 kg ha^{-1}, under different planting methods. They found that transplanting method with urea super granules proved to be the best for maximum grain yield (4.53 t ha^{-1}).

Kumar *et al.* (1996) reported that application of urea super granule (USG) in the subsoil gave 22% higher grain yield than control.

Budhar and Palaniappan (1993) conducted a field trial in the rainy season with rice cv. Jalmagna, which was given 30 or 60 kg N ha^{-1} as PU, lac coated urea (LCU) or USG applied as basal, split or deep placement and reported that grain yield increased with the rate of N application and were highest with deep placement of USG.

Mishra *et al.* (1999) conducted a field experiment with urea super granule (USG) in wetland rice (*Oryza sativa cv. Lalat*) in a fine textured soil. Urea super granule was applied at 76 kg N ha^{-1} along with prilled urea (PU) as split. They found that placement of USG significantly increased both the grain and straw yield of rice compared to PU.

Bastia and Sarker (1995) reported that grain yield and N content were the highest with USG (4.07 t ha^{-1} and 1.43%, respectively) and the lowest with the PU (2.66 t ha^{-1} and 1.31 %, respectively).

Bhale and Salunke (1993) conducted a field trial to study the response of upland irrigated rice to nitrogen applied through urea and USG. They found that grain yield increased up to 120 kg urea and 100 kg USG.

Das and Singh (1994) pointed out that grain yield of rice cv. RTII-2 during *kharif* season was higher for deep placed USG than USG for broadcast and incorporated or three split applications of PU.

Zaman et al. (1993) found that USG consistently produced significantly higher grain yield than PU.

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

Ahmed *et al.* (2000) conducted an experiment during the *Kharif* season of 1998 at the 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 at 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^{-1} as USG and significantly superior to that obtained from any other level and source of N.

Pandey and Tiwari (1996) evaluated the rate of 87 kg N ha^{-1} as a basal application of USG and to dressing as PU and observed that grain yield and N use efficiency were the highest with N applied as a basal application of USG.

2.10 Increasing Nitrogen Use Efficiency in Rice through USG Management

Nitrogen undergoes dynamic transformation under different soil, environment, and cropping management factor. For this it had been researched extensively. A better understanding of the soil, crop and environmental factors for managing N-fertilizer was a prerequisite to maximize fertilizer use efficiency.

Many studies indicate that N fertilizers are not used efficiently by the rice plant because rice is grown in an environment that is conducive to N losses from nitrification, dentrification, ammonia volatilization, run off and leaching. Imbalance use of fertilizers and occurrence of other macronutrients deficiencies have also given rise to low N-use efficiency (Von Uexkull, 1993).

Nitrogen fertilizer use efficiency is relatively low in irrigated rice because of rapid N losses from volatilization and de-nitrification in the soil (De Datta and Buresh, 1989).

Siddika (2007) conducted an experiment by using prilled urea and urea super granules and found that N-use efficiency was higher from USG in compared to prilled urea. Mishra *et al.* (1999) reported that the N use efficiency of rice was increased from 18 kg grain kg^{-1} N applied as PU to as high as 26 kg grain kg^{-1} N applied as USG. Similarly, the relative efficiency of USG was increased was increased by 40% over PU. The apparent N recovery in rice was 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.

Jena *et al.* (2004) reported that efficiency of urea super granules for increasing rice grain yield in flooded condition is well established. Zaman *et al.* (1993) found that USG consistently produced significantly higher grain yield than PU. Also, the total N uptake, apparent N recovery and agronomic efficiency of nitrogen (AEN) were higher with USG than PU. A similar result was observed by Singh *et al.* (1993) and Bhagat *et al.* (1992).

Jena *et al* .(2003) studied, the use efficiency of nitrogen and volatilization losses of ammonia in rice by using PU and USG at 76 and 114 kg N ha^{-1} respectively in a field experiment and reported that application of USG at 76 kg N ha^{-1} was adjusted to be the optimum source of fertilizer N for rice. Deep placement of USG significantly improved grain yield, straw yield and nitrogen use efficiency of rice and reduced the volatilization loss of ammonia related to the application of PU.

Singh and Kumar (2003) conducted an experiment and observed the application of slow release fertilizers (USG), biogas slurry and blue green algae + prilled urea (PU) significantly increased grain and straw yield, nitrogen uptake, nitrogen use efficiency, and nitrogen recovery in rice. The highest grain yield and nitrogen recovery were recorded with the application of USG.

Dash *et al.* (2003) reported that deep placement of 76 kg USG ha^{-1} at 5 cm soil depth produced significantly higher grain (43.1q ha^{-1}) and straw (47.8q ha^{-1}) yields with highest mean N use efficiency (24.13 kg grain kg^{-1} N applied). The study suggested that 76 kg USG ha^{-1} is the optimum rate of urea as USG.

From the reviews cited above, it is clear that urea super granules (USG) have pronounced influence on the yield contributing characters and yield of rice plant. Many research workers reported that doses of USG had different effects on crop characters and yield of transplant *aman* rice and also showed the higher N-use efficiency. So, yield and its contributing characters are greatly affected. Thus there may have enough scope of investigating into the effect of different doses of USG compared to prilled urea in favor of yield improvement of transplant *aman* rice in the tidal coastal area of greater Khulna region.

CHAPTER 3

MATERIALS AND METHODS

The field experiment was conducted at Prof. Purnendu Gain Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna, during the *aman* season from July- December, 2011 to observe the effect of urea super granule deep placement on rice cultivation in the tidal coastal area of Khulna region. The materials used and the methodologies followed in the present investigation have been described in this chapter.

3.1 Description of the Experimental Site

3.1.1 Location

The experimental site is located at the latitude of $22^0 47'$ N and longitude of $89^0 34'$ E. It belongs to the Agro ecological zone of Ganges Tidal Floodplain (AEZ-13). The experimental field was a typical rice growing medium high land under physiographic unit of Ganges Tidal Flood Plain soil.

3.1.2 Soil

The soil of the experimental field was more or less neutral in reaction with P^H value 7.6, low in organic matter content (2.23%) and the general fertility level of the soil was also low. The physical properties and chemical composition of the soil have been presented in Appendix 1.

3.1.3 Climate and weather

The climate of the area is subtropical. It is characterized by high humidity and moderately low temperature during *rabi* season (October to March) and high temperature and heavy rainfall with occasional gusty winds during *kharif* season (April to September). The monthly average temperature (^{0}c), rainfall (mm) and relative humidity (%) during the period of experiment have been presented in Appendix 2.

3.2 Experimental Treatments

The study consisted of the following treatments:

Treatment-1 (T_1) = Without Nitrogen (control).

Treatment-2 (T_2) =Recommended N as Prilled Urea (PU), i.e. PU-216 kg ha^{-1}

Treatment-3 (T_3) = Recommended N as Urea Super Granules (USG), i.e. USG- 216 kg ha^{-1}.

Treatment-4 (T_4) = 75% recommended N as Urea Super Granules, i.e. USG- 162 kg ha^{-1}.

Treatment-5 (T_5) = 50% recommended N as Urea Super Granules, i.e. USG- 108 kg ha^{-1}.

Treatment-6 (T_6) = 125% recommended N as Prilled Urea, i.e. PU-270 kg ha^{-1}.

Treatment-7 (T_7) = 125% recommended N as Urea Super Granules, i.e. USG- 270 kg ha^{-1}.

3.3 Planting Material Used

Rice variety BR23 was taken as experimental material which was developed by the Bangladesh Rice Research Institute from a cross between DA 29 and BR 4 and was released in 1988. The popular name of this variety is 'Dishari'. This is a photo sensitive tall variety and to some extent saline tolerant. It is also considered as a late variety, and similar to a variety resist to water logged conditions. So the variety is suitable for tidal coastal area of greater Khulna region.

3.4 Forms of Urea

3.4.1 Prilled urea

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

3.4.2 Urea super granule (USG)

It can be produced directly in the factory either by using modified granular machine or by using roll press machine. It has been developed by the IFDC, Muscle Shoals, Alabama 35660, and USA. There are three different sizes of pellets or granules. The size of USG may range from 0.9-2.7g in weight. Its nature and properties are similar to that of urea but its granule size is bigger and condensed with some conditions for slow hydrolysis. Urea Super Granule (USG) is spherical in shape containing 46% nitrogen. Average diameter of the granule is 11.5mm. It is actually not a slow-release fertilizer but can be considered as a slowly available N fertilizer. It can easily be placed in reduced layer as deep placement.

3.5 Experimental Design and Layout of the Experiment

The experimental design was Randomized Complete Block Design (RCBD) with three replications of seven treatments having a total field size of 210 m^2. In the main field there were 21 (7x3) plots were. The size of unit plot was 4m x 2.5m and the distance between plot to plot and also block to block was 1m. Treatments were assigned randomly in the unit plots.

3.6 Raising of Seedling

3.6.1 Seed collection

Healthy and vigorous rice seeds of BR23 were collected from BADC Sales Centre, Daulatpur, Khulna.

3.6.2 Seed sprouting

The collected seeds were soaked for 3 days and then soaked seeds were kept in a gunny bag for sprouting. The seeds started sprouting after 4 days.

3.6.3 Preparation of seedling nursery and seed sowing

A piece of high land was selected at the Agronomy Field laboratory, Khulna University, Khulna for raising seedlings. The size of nursery bed was 4m x 3m and prepared by ploughing 4 times followed by laddering. The land was puddlled, stubbles were removed, cleaned and leveled by laddering. Then the sprouted seeds were sown in the nursery bed on 10 July 2011. Care was taken to protect them from attack of birds and infestation of pest and diseases. Weeds were removed from the seed bed, thinning operations were done and irrigation was given two times in the nursery bed as required.

3.7 Preparation of Experimental Land

The experimental field was opened before 15 days of transplanting with a power tiller. It was prepared thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering.

Weeds and stubbles were removed and the field was then divided in to unit plot according to the design immediately after final land preparation.

3.8 Fertilizer Application

3.8.1 Basal dose

All treatments received a basal application during final land preparation at the following rate:

Triple Super Phosphate:	74 kg ha^{-1}
Muriate of Potash:	33 kg ha^{-1}
Gypsum:	22 kg ha^{-1}
Zinc Sulphate:	05 kg ha^{-1}

3.8.2 Application of prilled urea

Prilled urea in the concerned plots (T_2 and T_6) was given in to three equal splits (as per doses mentioned in the respective treatments), at 08 DAT, 23 DAT and 40 DAT.

3.9 Uprooting of Seedlings

The seedlings were uprooted carefully from the nursery bed, bundled with proper care, distributed in the plots and kept on soft mud before they were transplanted. The seedlings similar in size having no injury were used for transplanting.

3.10 Transplanting of Seedlings

Forty day old seedlings were transplanted in the experimental field with a spacing of 20 cm x 20 cm on 20 August, 2011 according to the experimental design. Two or three seedlings $hill^{-1}$ was transplanted, since there was high standing rain water during that period.

3.11 Application of USG

The pellet/ pellets was/were placed in the centre of four hills at 8-10 cm depth of a line; the next centre of four hills of the same line was left without application of USG pellet/pellets and then again as before. In this way the USG was applied. The rate of USG has been mentioned in the concerned treatment. The USG was applied at 8 days after transplanting of seedlings.

3.12 Intercultural Operations

To keep the experimental field free from the weed infestation 3 hand weedings were done. The experimental field received sufficient amount of rain water and no irrigation was required. During the experiment some insects pests like grasshopper, stem borer, ant and fungal disease incidence like brown spot of rice were noticed. Insecticide 'Nitro' and fungicide 'Score' were used to control them.

3.13 General Observation of the Experimental Field

The field looked nice with normal green plants. The plants in of higher nitrogen doses appeared to move vigorous and luxuriant than that of less nitrogen doses. Incidence of stem borer was observed during the tillering stage. However, it was not severe to damage the standing crops. The plant did not lodge in any plot. The green colors of the plants were not uniform in different plots because of the different rates of urea.

3.14 Harvesting and Post Harvest Operations

The crops were harvested at their full maturity stage when more than 80% of the seeds turned into golden yellow color. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. Then the bundles were dried in open sunshine. The seeds were cleaned after threshing. The grain and straw weight for each plot were recorded after proper drying. The grain and straw weight were adjusted to 14% moisture content. Grain and straw yield plot^{-1} were converted to t ha^{-1}.

3.15 Data Collection

Before harvesting 5 hills were collected randomly from each plot for data collection. Data were collected on the following parameters -

- Plant height (cm)
- Number of tillers hill^{-1}
- Number of effective tillers hill^{-1}
- Total dry matter (kg m^{-2})
- Crop growth rate (kg m^{-2}d^{-1})
- Length of panicle (cm)
- Number of filled grains panicle^{-1}
- Number of unfilled grains panicle^{-1}
- 1000 grain weight (g)
- Grain yield (t ha^{-1})
- Straw yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Harvest index (%)

3.15.1 Procedure of collecting data

A brief outline of the data recording procedure is given below:

Plant height (cm)

Plant height was measured from the ground level to the tip of the longest panicle.

Total number of tillers hill^{-1}

Tillers which had at least one leaf visible were counted. It included both effective and non effective tillers.

Number of effective tillers hill^{-1}

Tillers having panicles which had at least one grain were considered as effective tillers.

Panicle length (cm)

Panicle length was measured from the basal node of the rachis to the apex of each panicle.

Number of grains panicle^{-1}

Presence of any food material in the spikelet was considered as filled grain and total number of grains present on each panicle was counted.

Weight of 1000-grain (g)

The weight of 1000 seeds was taken from the seed stock obtained from the sample plants of each plot and weighed by using an electrical balance and expressed in g.

Total dry matter (kg m^{-2})

Total dry matter (TDM) is the product of crop growth rate (CGR) and growth duration (Tanaka, 1983). Before harvest, at different DATs randomly four sample hills plot^{-1} were sun dried for 4 days and then dry weight was recorded with the help of an electrical balance. Then it was converted to kg m^{-2}.

Crop Growth Rate (kg m^{-2} day^{-1})

CGR was calculated with following formula:

$$\text{CGR} = \frac{1}{\text{Ground Area}} \text{X} \frac{\text{Difference of dry weight of two consecutive DATs}}{\text{Difference in days of two consecutive DATs}}$$

Grain yield (t ha^{-1})

Grains obtained from each unit plot were sun dried and weighed carefully. The dry weight of grains of five sample plants were added to the respective unit plot yield to record the final grain yield plot^{-1}. The grain yield was finally converted to t ha^{-1}.

Straw yield (t ha^{-1})

Straw obtained from each unit plot including the straw of five sample plants of respective unit plot were sun dried and weighed to record the straw yield plot^{-1} and finally converted to t ha^{-1}.

Biological yield (t ha^{-1})

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated using the following formula:

Biological yield = Grain yield + Straw yield.

Harvest index (%)

Harvest index was calculated on the basis of grain yield and straw yield using the following formula (Gardner *et al.*, 1985).

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

3.16 Statistical Analysis

The collected data were compiled and analyzed statistically following the analysis of variance (ANOVA) technique and the significance of the mean differences were adjusted by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a statistical computer package program "MSTAT-C".

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was carried out in order to evaluate the effect of urea super granule deep placement on rice in the tidal coastal area of Khulna region. The rice variety BR23 was selected as experimental material. Seven different forms and doses of urea were included in the experiment as treatments. The data obtained on plant height, number of tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, number of grains panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight, grain yield, straw yield, biological yield, dry matter, crop growth rate and harvest index have been presented in the Tables 1-5. The results of the experiment have been presented and discussed in this chapter.

4.1 Effect on Growth Characters

4.1.1 Plant height

The various forms and doses of urea had significant influence on plant height of rice (Table1). Plant height gradually increased up to maturity irrespective of all treatments. At harvest the tallest plant (134.4 cm) was obtained when deep placed USG was applied @ 216 kg ha^{-1} which was statistically similar to other treatments except without nitrogen (control) and PU 216 kg ha^{-1}. The lowest plant height (118.67 cm) at harvest was found in the control treatment (WN). In case of 50, 80 and 95 DAT the tallest plant (101.8, 123.5 and 132.33 cm, respectively) were observed in the same treatment i.e. USG @ 216 kg ha^{-1} but in case of 35 and 65 DAT the highest plant height (86.07 and 114.9 cm, respectively) were observed in USG @ 108 kg ha^{-1} and USG @ 270 kg ha^{-1}, respectively. The shortest plant in case of 35, 50, 65, 80 and 95 DAT (68.0, 77.87, 88.53, 97.53 and 106.1 cm, respectively) was found in the control treatment i.e. without nitrogen. Probably, the steady supply of nitrogen by USG was the reason behind the highest plant height. Similar result was

Table 1. Effect of urea deep placement on plant height (cm) of aman rice (BR 23) at different days after transplanting (DAT)

	Plant height (cm)					
Treatments	35 DAT	50 DAT	65 DAT	80 DAT	95 DAT	At harvest
WN (Control)	68.00c	77.87d	88.53b	97.53d	106.1c	118.67 c
PU-216 kg ha^{-1}	80.13ab	92.40bc	105.80a	112.7bc	121.30b	126.87 b
USG-216 kg ha^{-1}	84.00ab	101.8a	114.7a	123.5a	132.33a	134.4a
USG-162 kg ha^{-1}	85.73a	100.3a	113.1a	118.1abc	131.47a	132.7a
USG-108 kg ha^{-1}	86.07a	97.07ab	108.4a	118.9abc	128.9ab	129.07ab
PU-270 kg ha^{-1}	78.53b	89.87c	106.6a	111.60c	120.9b	127.93ab
USG-270 kg ha^{-1}	84.93ab	100.5a	114.9a	122.1ab	129.33ab	131.90a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Coefficient of variation (%)	3.42	2.73	4.10	3.38	2.23	1.75

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

WN = Without nitrogen; PU = Prilled urea; USG = Urea super granule.

observed by Vijaya and Subbaiah (1997) who recorded the highest plant height with the deep placement method of USG application compared with broadcasting method of prilled urea (PU).

4.1.2 Number of tillers hill^{-1}

The effect of different forms and doses of nitrogen was found to be significant in respect of total tillers hill^{-1} (Table 2). The data in the table revealed that the highest number of total tillers hill^{-1} was found in case of 35, 50, 65, 80 and 95 DAT (16.4,13.53, 11.87, 10.73 and 9.53, respectively) by the deep placement of USG @ 216 kg ha^{-1}. But at harvest the highest number of total tillers hill^{-1} was observed when prilled urea was applied in 25% more than the recommended dose, i.e. 270 kg ha^{-1} which was statistically similar to other treatment except the control treatment. It might be due to the higher absorption of N from higher dose of nitrogen. The lowest number of total tillers hill^{-1} was produced by the control treatment (WN) at all DATs as well as at harvest. The variation in number of tillers hill^{-1} as assessed might be due to the source and adequacy of nitrogen, which enhanced tillering. Rama *et al.* (1989) remarked that the highest number of tillers was produced by USG than the application of prilled urea (PU).

4.1.3 Total dry matter (kg m^{-2})

The effect of different forms and doses of urea was significant in regard to total dry matter (TDM) production at different dates of observation except 35 DAT (Table 3). The highest amount of TDM was recorded at 50, 65, 80 and 95 DAT (4.12, 5.95, 6.9 and 7.43 kg ha^{-1}, respectively) by deep placed USG @ 270 kg ha^{-1} , while the least was accumulated by the control treatment i.e. without any application of urea irrespective of all DATs.

Table 2. Effect of urea deep placement on number of tiller hill^{-1} of aman rice (BR 23) at different days after transplanting (DAT)

Treatments	35 DAT	50 DAT	65 DAT	80 DAT	95 DAT	At harvest
WN (Control)	9.67 c	7.73 c	7.73 c	7.07 b	6.80 b	7.47 b
PU-216 kg ha^{-1}	11.53 bc	11.27 b	9.93 b	9.13 a	8.70 a	9.53 a
USG-216 kg ha^{-1}	16.40 a	13.53 a	11.87 a	10.73 a	9.53 a	10.0 a
USG-162 kg ha^{-1}	13.87ab	13.47 a	11.73 a	9.53 a	8.97 a	9.8 a
USG-108 kg ha^{-1}	15.47 a	12.80ab	10.87ab	9.47 a	8.93 a	9.73 a
PU-270 kg ha^{-1}	13.73ab	13.00ab	11.73 a	10.07 a	9.40 a	10.33 a
USG-270 kg ha^{-1}	14.73ab	12.93ab	11.27ab	9.73 a	9.27 a	10.27 a
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Coefficient of variation (%)	11.24	9.40	7.16	8.58	7.49	4.52

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

WN = Without nitrogen; PU = Prilled urea; USG = Urea super granule.

Table 3. Effect of urea deep placement on dry matter (Kg m^{-2}) production of aman rice (BR23) at different days after transplanting (DAT)

Treatments	35 DAT	50 DAT	65 DAT	80 DAT	95 DAT
WN (Control)	1.63	2.29 b	2.8 c	3.67 c	4.78 c
PU-216 kg ha^{-1}	2.4	3.38 a	4.37 b	5.25 b	6.27 b
USG-216 kg ha^{-1}	2.68	3.77 a	4.8 b	5.67 b	7.00ab
USG-162 kg ha^{-1}	2.49	3.83 a	4.95ab	5.93ab	6.63ab
USG-108 kg ha^{-1}	2.36	3.97 a	5.03ab	6.02ab	6.72ab
PU-270 kg ha^{-1}	2.09	3.54 a	4.77 b	6.17ab	6.83ab
USG-270 kg ha^{-1}	2.4	4.12 a	5.95 a	6.9 a	7.47 a
Level of significance	NS	0.01	0.01	0.01	0.01
Coefficient of variation (%)	17.37	12.78	9.28	7.95	6.71

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

WN = Without nitrogen; PU = Prilled urea; USG = Urea super granule; NS= Not significant.

4.1.4 Crop growth rate (kg m^{-2} day^{-1})

Crop growth rate (CGR) in case of 35 DAT-50 DAT and 65 DAT-80 DAT did not show any significant difference due to forms and doses of urea application, but was significantly influenced at 50 DAT-65 DAT and 80 DAT-95 DAT at 1% and 5% level of significance, respectively. Results of table 4 show that the highest CGR (0.123) was obtained at 50 DAT- 65DAT when N-fertilizer was applied @ 270 kg ha-1 as USG and that was the lowest (0.030) in control treatment (WN). But at 80 DAT- 95DAT the highest CGR (0.087) was observed when USG was applied @ 216 kg ha-1 and the lowest one (0.037) was recorded by the treatment USG @ 270 kg ha-1.

4.2 Effect on Yield and Yield Attributes

4.2.1 Number of effective tillers $hill^{-1}$

Significant effect was found among the different forms and doses of urea application in case of number of effective tillers $hill^{-1}$ (Table 5). Numerical data shows that the highest number of effective tillers $hill^{-1}$ (8.87) was produced by the treatment PU-270 kg ha^{-1} which was statistically similar to USG-216 kg ha^{-1} (8.6), USG-270 kg ha^{-1} (8.53), PU-216 kg ha^{-1} (8.47), USG-108 kg ha^{-1} (8.27), and USG-162 kg ha^{-1}(8.0). The lowest number of effective tillers $hill^{-1}$ (6.13) was produced by the control treatment (WN). Adequacy of nitrogen probably favored the cellular activities during development which led to increase number of productive tillers $hill^{-1}$. Singh and Singh (1986) mentioned that the number of effective tillers m^{-2} was significantly higher in USG than prilled urea (PU) which was somewhat dissimilar with this observation.

4.2.2 Panicle length (cm)

No significant variations were observed in panicle length with the application of

Table 4. Effect of urea deep placement on crop growth rate (kg $m^{-2}day^{-1}$) of transplant aman rice (BR23)

Treatments	35DAT-50DAT	50DAT-65DAT	65DAT-80DAT	80DAT-95DAT
WN (Control)	0.047	0.030 c	0.057	0.077 a
PU-216 kg ha^{-1}	0.067	0.063 b	0.057	0.070 a
USG-216 kg ha^{-1}	0.073	0.067 b	0.057	0.087 a
USG-162 kg ha^{-1}	0.093	0.083 b	0.063	0.047 b
USG-108 kg ha^{-1}	0.107	0.070 b	0.063	0.047 b
PU-270 kg ha^{-1}	0.097	0.080 b	0.093	0.043 b
USG-270 kg ha^{-1}	0.113	0.123 a	0.063	0.037 b
Level of significance	NS	0.01	NS	0.05
Coefficient of variation (%)	39.04	23.28	22.98	26.91

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

WN = Without nitrogen; PU = Prilled urea; USG = Urea super granule; NS= Not significant.

different forms and doses of urea (Table5). However, numerically the longest panicle length (22.19 cm) was produced when USG was deep placed @ 216 kg ha-1followed by panicle length (21.71 cm) obtained due to the application of USG @ 108 kg ha-1. The shortest one (20.57 cm) was found when no nitrogen was applied. Almost similar variations were found by Rahman (2003) who reported that panicle length differed significantly due to level of USG. The result was also in confirmatory to the experiment of Sarder et al. (1988) who showed that USG gave greater panicle length than those of other N sources.

4.2.3 Number of grains panicle^{-1}

Number of grains panicle-1 varied significantly at 1% level of probability due to differences in forms and doses of urea (Table 5). The highest number of grains panicle-1(126.9) was achieved from the deep placement of USG @ 216 kg ha-1 and the lowest one (102.3) was recorded from control treatment (Table 5). Adequate and long time supply of nitrogen through USG contributed to grain formation which probably increased number of grains panicle-1 in this treatment.

4.2.4 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} differed significantly (Table 5) among the treatments by application of various forms and doses of nitrogen. It was revealed that deep placed USG @ 216 kg ha^{-1} produced the highest number of filled grains panicle^{-1} (100.8) followed by treatments USG @ 108 kg ha^{-1} (86.51) and USG @ 162 kg ha^{-1} (84.43) which were statistically similar. The lowest number of filled grains panicle^{-1} (75.79) was found from the application of PU @ 216 kg ha^{-1} which was statically similar to rest of the treatments. The finding was in agreement with Surendra *et al.* (1995) where

Table 5. Effect of urea deep placement on yield and yield attributes of transplant aman rice (BR23)

Treatments	Number of effective tiller $hill^{-1}$	Panicle length (cm)	Number of grains $panicle^{-1}$	Number of filled grains $panicle^{-1}$	1000 grains weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
WN (Control)	6.13b	20.57	102.3c	76.15c	29.85b	4.98 c	7.72	12.71	39.27
PU-216 kg ha^{-1}	8.47a	21.47	107.6bc	75.79c	30.23b	5.08c	11.22	16.31	31.28
USG-216 kg ha^{-1}	8.60a	22.19	126.9a	100.8a	31.98a	5.79a	10.42	16.21	35.78
USG-162 kg ha^{-1}	8.00a	21.32	111.0b	84.43b	31.59a	5.60a	10.45	16.05	35.34
USG-108 kg ha^{-1}	8.27a	21.71	109.2b	86.51b	31.39a	5.60a	11.38	16.99	33.42
PU-270 kg ha^{-1}	8.87a	21.32	108.3bc	78.05c	31.59a	5.56a	11.40	16.96	33.28
USG-270 kg ha^{-1}	8.53a	21.15	107.1bc	79.61c	31.59a	5.31b	11.09	16.40	32.56
Level of significance	0.01	NS	0.01	0.01	0.01	0.01	NS	NS	NS
Coefficient of variation (%)	5.8	2.13	2.18	2.21	1.16	1.79	16.12	10.56	10.09

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

WN = Without nitrogen, PU = Prilled urea, USG = Urea super granule, NS= Not significant.

they found that USG produced significantly higher number of filled grains panicle^{-1} than PU.

4.2.5 1000 grain weight (g)

Various forms and doses of urea exerted significant influence on 1000- grain weight (Table 5). Maximum grain weight (31.98 g) was obtained by deep placed USG @ 216 kg ha^{-1} followed by the treatments USG @ 162 kg ha^{-1} (31.59 g), USG @ 270 kg ha^{-1} (31.59 g), PU @ 270 kg ha^{-1} (31.59 g) and USG @ 108 kg ha^{-1}(31.39 g). The lowest 1000 grain weight (29.85 g) was found in control treatment WN, which was statistically similar to the treatment PU @ 216 kg ha^{-1} (30.23 g). Thakur (1991) reported that the maximum 1000 grain weight was obtained from USG which was also observed in the present study.

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

From the study it was found that grain yield was significantly influenced by different forms and doses of urea application at 1% level of probability (Table 5). The grain yield was the highest (5.79 t ha^{-1}) with deep placement of USG applied at 216 Kg ha^{-1}. The second highest grain yield (5.60 t ha^{-1}) was obtained from USG applied at 162 and 108 kg ha^{-1}. The longest panicle length, the highest number of filled grains panicle^{-1} and the highest 1000 grain weight probably contributed to the production of highest grain yield. Mishra *et al.* (1999) was in agreement with this observations because they found that deep placement of USG significantly increased the grain yield of rice compared to prilled urea (PU).The lowest grain yield (4.98 t ha^{-1}) was obtained from control.

Grain yield showed a positive and linear relationship with total number of effective tiller hill^{-1} (Fig. 1). The value (R^2=0.3625) suggests that over 30% of the variation in grain yield could be explained by the variation in number of effective tiller hill^{-1}.

Grain yield (t ha^{-1}) when plotted against total number of filled grains panicle^{-1} produced a straight line. This suggests that grain yield (t ha^{-1}) is dependent on number of filled grains panicle^{-1} and more than 60% (R^2=0.63) of the variation in grain yield is defined by variation in number of filled grains panicle^{-1} (Fig. 2).

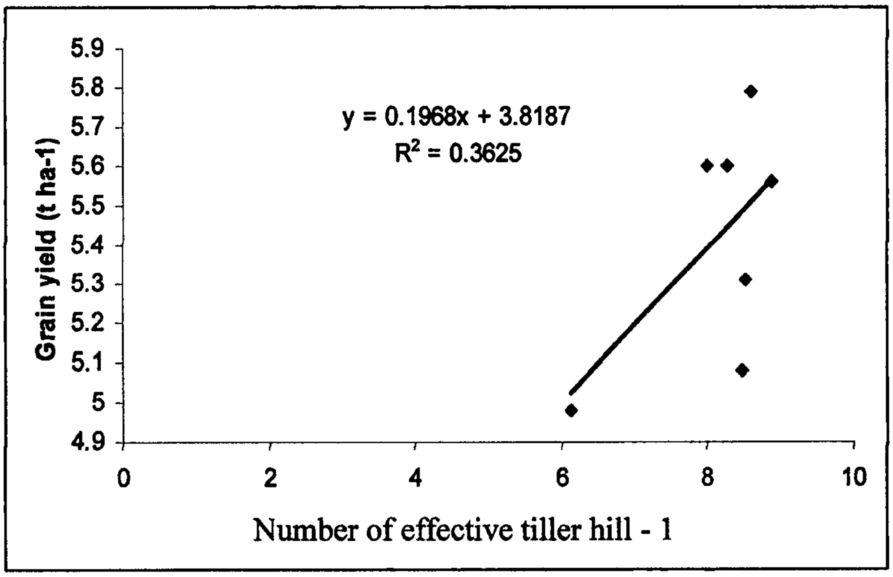

Fig.1. Functional relationship between grain yield and number of effective tillers hill^{-1} in rice

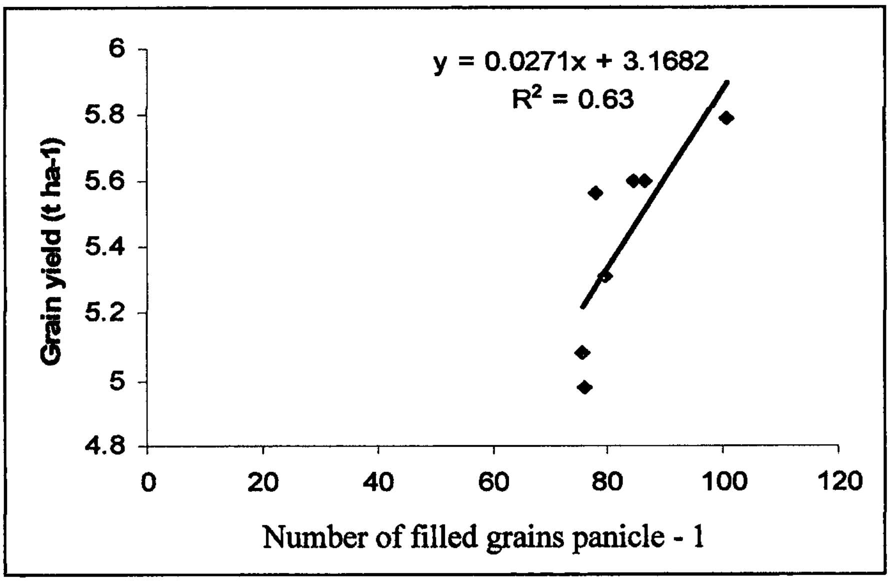

Fig.2. Functional relationship between grain yield and number of filled grains panicle^{-1} in rice

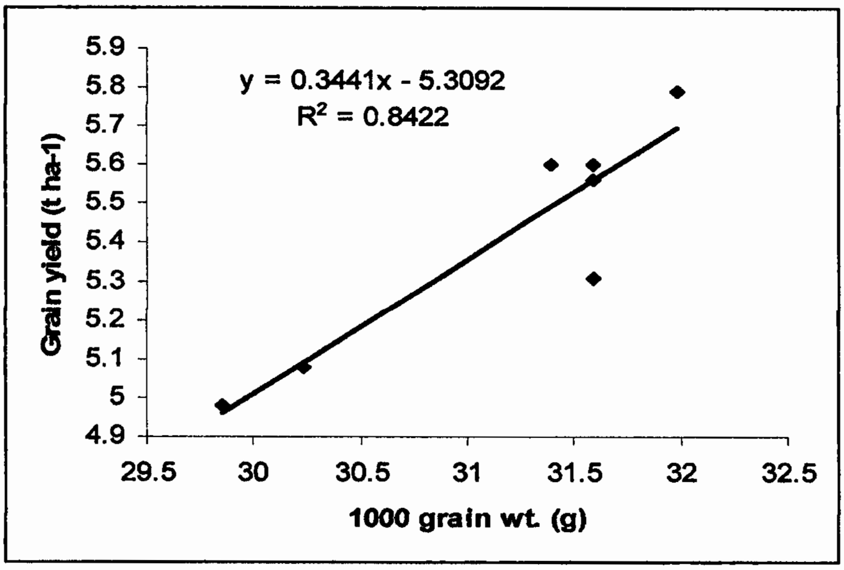

Fig.3. Functional relationship between grain yield (t ha^{-1}) and 1000 grain weight

Grain yield showed a positive and linear relationship with 1000 grain weight. The higher value (R^2 =0.8422) suggests that over 84% of the variation in yield could be defined by the variation in 1000 grain weight (Fig.3).

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

The effect of various forms and doses of urea was found not to be significant in respect of straw yield (Table 5). PU 270 kg ha^{-1} produced the highest straw yield (11.40 t ha^{-1}) and the lowest (7.72 t ha^{-1}) was obtained from 0 kg N ha^{-1}.This result was not confirmatory to the experiment of Swain *et al.* (1995) who evaluated the performance of USG application and noted that USG gave higher straw yield.

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

The forms and levels of urea on biological yield were not significant which might be due to the pattern of production of straw yield. The highest biological yield (16.96 t ha^{-1}) was produced by 270 kg PU ha^{-1}(Table 5). On the contrary, the lowest biological yield

($12.71 t\ ha^{-1}$) was recorded at 0 kg N ha^{-1}. Such results might have obtained due to absence of sufficient nitrogen in soil as for not applying urea in that treatment.

4.2.9 Harvest Index (%)

There were no significant variations among the treatments in relation to harvest index of rice with the application of various forms and doses of nitrogen (Table 5). The highest harvest index (39.27%) was recorded from 0 kg N ha^{-1} and the lowest one (31.28%) was obtained at PU @ 216 kg ha^{-1}.

From the above discussion, it is observed that by using USG, maximum N was taken up by rice plant to convert it into dry matter for producing grains. As a result, maximum utilization of N was possible due to proper application of N as deep placed USG. If the doses of nitrogen are higher or lower than actual need, it will be overdose or deficiency of N and then yield will be reduced as well as production cost may be increased. So, it can be concluded that USG should be used as N management to achieve better nitrogen use efficiency without reducing yield and reducing nitrogen loss than the PU.

CHAPTER 5

SUMMARY AND CONCLUSION

A piece of research work was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna, during *aman* season, 2011 in order to evaluate the effect of urea super granule deep placement on rice cultivation in the coastal area of Khulna region. The experiment was laid out in a randomized complete block design (RCBD) with seven treatments and three replications. The doses and forms of urea for various treatments were without nitrogen (WN), recommended N as prilled urea (PU - 216 kg ha^{-1}), recommended N as urea super granules (USG - 216 kg ha^{-1}), 75% recommended N as USG (USG-162 kg ha^{-1}), 50% recommended N as USG (USG-108 kg ha^{-1}, 125% recommended N as PU (PU-270 kg ha^{-1}) and 125% recommended N as USG (USG-270 kg ha^{-1}). The unit plot size was $10m^2$ (4m x 2.5m). The whole amount of TSP, MoP, Gypsum and Zinc sulphate were broadcasted as basal @ 74, 33, 22 and 05 kg ha^{-1}, respectively. The nitrogen fertilizer was applied as per treatment requirement in the form of prilled urea and urea super granule. Prilled urea was applied in equal three splits. Urea super granule was placed manually at 8-10 cm depth of soil in the middle of four consecutive hills of two adjacent rows at eight days after transplanting (DAT) as per experimental specification. Forty day old seedlings were transplanted on 20 August,2011 maintaining row and hill spacing of both 20 cm. Intercultural operations were done with a view to ensure and maintain the normal growth of the crop as and when necessary. When more than 80% of the seeds became golden yellow in color, five hills (excluding border hills) were randomly selected from each unit plot for recording data on different agronomic characters. The grain and straw weight for each plot was taken on whole plot basis and were recorded after proper drying. The grain and straw weight were adjusted to 14% moisture content. Data were analyzed using the "Analysis of Variance" technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT).

The used PU and USG exhibited their differences in most of the cases. The result revealed that different agronomic characters of rice were not found to be increased linearly with the increasing doses of nitrogen.

The forms and doses of urea had significant effect on most of the parameters. Urea super granule @ 216 kg ha^{-1} produced the tallest plant at harvest (134.4 cm), longest panicle (22.19 cm), highest number of filled grains $panicle^{-1}$ (100.8) and highest 1000-grain weight (31.98 g). As a result it produced the highest grain yield (5.79 t ha^{-1}).

Statistically identical grain yield (5.60 t ha^{-1}) was obtained from two other USG treatments (USG @ 162 kg ha^{-1} and USG @ 108 kg ha^{-1}) which were also statistically similar to USG @216 kg ha^{-1} in case of other parameters.

On the other hand, the shortest plant (118.67 cm), lowest number of effective tillers $hill^{-1}$ (6.13), shortest panicle length (20.57 cm), lowest number of grains $panicle^{-1}$ (102.3) and lowest 1000 grain weight (29.85 g) were recorded from control (WU), which resulted in lowest grain yield (4.98 t ha^{-1}) and straw yield (7.72 t ha^{-1}).

The highest dose of 270 kg ha^{-1} urea as USG performed lower in all the yield contributing characters than the dose of 216 kg ha^{-1} as USG. The highest dose of 270 kg ha^{-1} urea as USG contributed the lower grain yield (5.31 t ha^{-1}) than another dose of 216 kg ha^{-1} as USG (5.79 t ha^{-1}).

Urea 270 kg ha^{-1} as PU produced also a lower plant height (127.93) at harvest, lower panicle length (21.32), lower number of filled grains $panicle^{-1}$(78.05) and lower 1000-grain weight (31.59). As a result this form and dose of urea also produced a lower grain yield (5.56 t ha^{-1}).

So it is revealed that, USG @ 216 kg ha^{-1}, 162 kg ha^{-1} and 108 kg ha^{-1} were better sources of nitrogen than others, while urea 270 kg ha^{-1} as USG indicated as the overdose of nitrogen for rice and PU caused loss of nitrogen in different ways.

Based on the above results, it can be concluded that farmers can use USG @ 216 kg ha^{-1} for higher production but 50% reduction of can be possible by using USG without significant yield loss. Hence it can be suggested that farmers should use USG @ 108 kg ha^{-1} as the best source and dose of nitrogen.

Such work needs to be further studied for more confirmation of the result.

CHAPTER 6

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APPENDICES

Appendix 1: Physical and chemical characteristics of soil (0-15 cm) of the experimental site.

Sl. No.	Name of the elements	Average amount of nutrients
1	p^H	7.6
2	Calcium (m.e./100g. soil)	22.75
3	Magnesium (m.e./100g. soil)	7.00
4	Potassium (m.e./100g. soil)	0.42
5	Total Nitrogen (%)	0.208
6	Phosphorus (µg/g soil)	4.01
7	Sulphur (µg/g soil)	458.55
8	Boron (µg/g soil)	0.77
9	Copper (µg/g soil)	10.32
10	Iron (µg/g Soil)	48.20
11	Manganese (µg/g soil)	19.66
12	Zinc (µg/g soil)	1.42
13	Organic matter (%)	2.23
14	Textural class	Clay

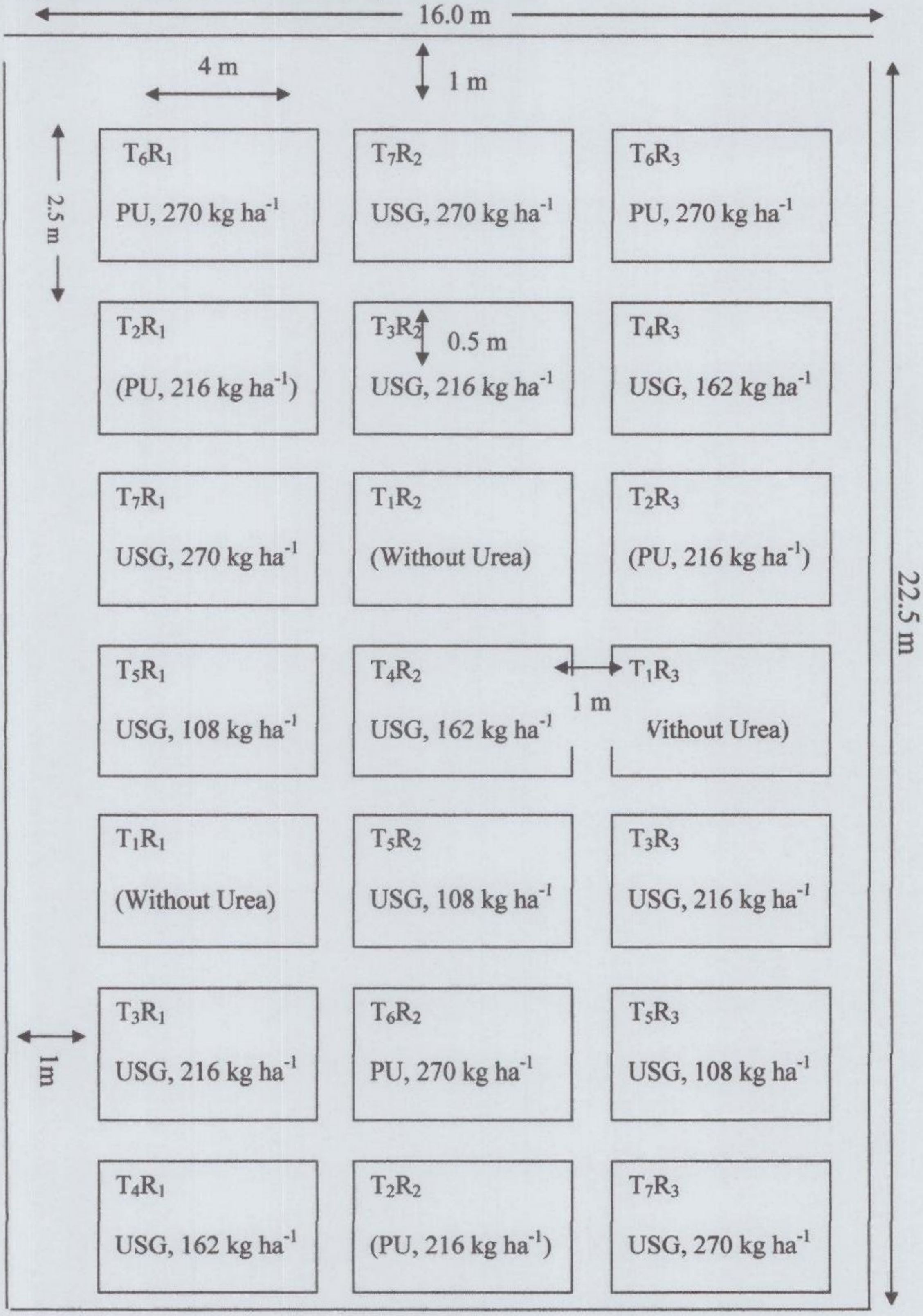
Note: Soil analysis was performed in Soil Resources Development Institute (SRDI), Daulatpur, Khulna.

Appendix 2: Monthly total rainfall, temperature and relative humidity during the growing period from July to December, 2011.

Month	Monthly average temperature (^0C)		Rainfall	Humidity
	Maximum	Minimum	(mm)	(%)
July	32.6	26.5	388	82.1
August	31.2	26.2	614	87.6
September	32.0	25.9	366	86.4
October	33.4	25.2	003	76.7
November	30.3	19.4	006	79.5
December	25.1	14.7	Nil	87.4

Source: Weather Department, Regional Observation Centre, Gollamari, Khulna.

Appendix 3: Layout of the main experimental field.



Total field size: 22.5 m X 16 m, Length and width of each plot: 4m and 2.5m.

R= Replication, T = Treatment, USG = Urea super granules, PU= Prilled urea.