COMPARISON OF DIFFERENT TECHNIQUES OF UREA APPLICATION IN RICE FIELD

A THESIS

BY

ASMA KHATUN

Examination Roll No.: 1505279

Session: 2015-2016

Thesis Semester: July-December, 2017

MASTER OF SCIENCE (MS)
IN
FARM POWER AND MACHINERY

DEPARTMENT OF AGRICULTURAL AND INDUSTRIAL ENGINEERING

HAJEE MOHAMMED DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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December, 2017

Dedicated

To

My Beloved Parents

&

Honourable

Teachers

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All praises are solely to the Almighty "ALLAH" whose blessings have enabled the author to complete the research work and to prepare this manuscript for the degree of Master of Science (M.S) in Farm Power and Machinery, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

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The Author

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ABSTRACT

A research work was carried out at the Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during the period from August 2016 to November 2016 to determine the suitable nitrogen source on the growth performance as well as the grain yield of Aman rice cv. Bina dhan-7. The soil was sandy loam in texture having pH 4.72, organic matter content 1.64%, total N 0.08%, available P 55.96 ppm, exchangeable K 0.21 me q 100 g^{-1} soil, available S 19.75 ppm. The experiment was laid out in a randomized complete block design with four treatments and three replications. The treatments were: T_1= 194 kg/ ha urea at two equal splits, T_2= Urea Super Granules @ 81.5 kg/ha (Only once), T_3= 2% foliar spray solution @ 45 kg/ha (Three times), T_4= Prilled urea 138kg/ha (Only once). The broadcast urea was applied after 11 days and 33 days of transplanting. The foliar urea was applied after 9 days, 24 days and 41 days of transplanting. USG and Prilled urea were applied after 7 days of transplanting at 8 cm depth among four hills in alternate rows. USG showed significant effect on all the yield and yield contributing characters of Aman rice. The result revealed that the highest grain yield (3.42 t ha^{-1}) was obtained from T_2 (Urea Super Granules @ 81.5 kg/ha) and the lowest grain yield (2.68 t ha^{-1}) was obtained from T_3 (2% foliar spray solution @ 45 kg/ha). The treatment T_2 (Urea Super Granules @ 81.5 kg/ha) produced 14.38% higher grain yield than traditional method T_1 (194 kg/ ha urea at two equal splits). It was also found that the highest straw yield (9.26 t ha^{-1})

was obtained from T_2 (Urea Super Granules @ 81.5 kg/ha) which was statistically different from other treatments T_1, T_3 and T_4. The deep placement of USG enhanced the recovery of applied N and N use efficiency in comparison with other application of urea. So the treatment T_2 (Urea Super Granules @ 81.5 kg/ha) may be recommended for profitable cultivation of Aman rice.

CONTENTS

CONTENTS (CONT.)

LIST OF THE TABLES

LIST OF THE FIGURES

LIST OF APPENDICES

CHAPTER 1

INTODUCTION

Rice (*Oryza sativa L.*) is one of the most important cereal crops of the world and the staple food of about 164.66 million people of Bangladesh intrinsically associated with their culture, rites and rituals. It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country. Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh (BRKB, 2011). In 2015-16, total rice area in three seasons reached to about 12 million ha, mainly due to increased cropping intensity and clean rice production increased to about 35 million ton (BRRI, 2016). Rice demand would increase by 25% to keep with population growth (Maclean *et al.,* 2002). At the end of the 2016, global rice production is estimated at 748.0 million tons. FAO anticipates Bangladesh will gather 53.1 million tons (35.4 million tons, milled basis) in 2017, up 1 percent year-on-year (FAO, 2017). In Bangladesh, agriculture contributes 14.79% of the gross domestic product (GDP) of the country (Bangladesh Finance Bureau, 2016-17).

There are three rice growing seasons namely Aush, Aman and Boro in Bangladesh. The majority of rice area is covered by Aman rice comprising 49.12% of the total rice area. Boro rice covers an area of 4.77 million hectares with a production of 18.94 million tons of grains (BBS, 2016).

The population of Bangladesh is increasing day by day and horizontal expansion of rice area is not possible due to high population pressure. Total rice production in Bangladesh was about 10.97 million tons in the year 1971 when the country's population was about 70.88 millions. At present the country is now producing about 34.71 million tons to feed her 156.6 million people (BBS, 2016). Population growth rate in Bangladesh is two million people per year and the population will reach 233.2 million by 2050, going by the current trend (BBS, 2012). Bangladesh will require more than 55.0 million tons of rice per year to feed its people by the year 2050. Bangladesh will require about 31.3 to 42.0 million tons of rice for the year 2030 (IFPRI, 2012). During this time total rice area will also shrink to 10.68 million hectares. Therefore, it is an urgent need of the time to increase rice production through increasing the yield. At present it is observed that rice yields are in stagnant condition, because farmers do not follow fully the improved techniques in an integrated way, which creates a yield gap. In this situation, farmers, researchers and scientists are looking for new methods or technologies to get higher yield of rice. New, front-line agronomic packages such as optimum plant population, seedling number per hill, optimum dose of N, split application of fertilizers and irrigation management, have a decisive effect on the yield potential of modern rice.

Judicious application of fertilizer is one of the most effective means for maximizing yield of rice. Nitrogen is a major essential plant nutrient and a key input for increasing crop yield. Yield increase (70-80%) of field rice could be obtained by the application of nitrogen fertilizer (Miah *et al.,* 2012). Optimum dose of nitrogen fertilization plays a vital role in growth and development of rice plant. BRRI (1990) reported that nitrogen has a positive influence on the production of effective tillers. Its growth is seriously hampered when lower dose of nitrogen is applied which drastically reduces yield. Nitrogen has a positive influence on the production of effective tillers per plant, yield and yield attributes. Total N uptake by rice plant ha^{-1} varies among rice varieties. Nitrogen is required in adequate amount at early, at mid-tillering and panicle initiation stage for better grain development (Ahmed *et al.,* 2005). Urea is the most frequently used N fertilizer globally. Urea can be applied in different ways such as USG (urea super granules), prilled urea, foliage spray and top dressing method. It is necessary to find out the suitable rate of nitrogen fertilizer for efficient management and better yield of rice.

In Bangladesh, farmer uses urea fertilizer by broadcast method during cultivation and most of the applied fertilizers are lost through volatilization, denitrification, run-off and leaching. These result in low crop yield and reduced efficiency of applied nutrients. However, heavy application of nitrogen does not always give higher yield. According to Craswell *et al.* (1980) broadcast application of urea on the surface soil causes losses up to 50% but point placement of USG in 10 cm depth results negligible loss. The nitrogen efficiency especially of urea fertilizer is very low (30-35%) in rice cultivation (IFDC, 2007).

Prilled urea (PU) is the most commonly used nitrogenous fertilizer for rice cultivation in Bangladesh. Prilled urea also plays a vital role in improving physical, chemical and biological properties of the soil and ultimately enhances crop production. The efficiency of nitrogenous fertilizer especially, PU in rice culture is about 25-30 per cent and rest 70-75 percent is lost for many reasons after application (BRRI, 2008). Khalil *et al.* (2009) reported that the volatilization loss of prilled urea (PU) is very high and farmers lose a huge amount of money for N fertilizer and proposed that to control this loss, deep placement of fertilizer might be a good option to minimize the production cost as well as to increase crop yield.

Urea can also be supplied to plants through the foliage, facilitating optimal N management, which minimizes N losses to the environment without affecting yield. This application technique is especially useful for micronutrients and thus it requires several applications to meet the needs of a crop. The increased efficiency reduces the need for soil applied fertilizer, reduces leaching and run-off of nutrients, reducing the impact on the environment of fertilizer salts. Foliar spray in bed planting method increased grain yield of transplanted Aman rice up to 9.33% over conventional method (Bhuyan *et al.,* 2012). Foliar nitrogen fertilizer application in bed planting method increased the number of panicle m^{-2}, number of grains $panicle^{-1}$, and 1000-grain weight of rice than the conventional method (Bhuyan *et al.,* 2012).

Deep placement of fertilizers is one of the most effective methods in reducing loss of nutrients in the flood water and is likely to minimize losses through different processes. Deep placement involves placement of large granules or briquettes of fertilizers at 8-10 cm below the surface. Urea Super Granules (USG) can minimize the loss of N from soil and hence the affectivity increased up to 20-25%. Urea deep placement (UDP) is a proven technology that reduces N losses by up to 50% when compared with the conventional broadcast application of urea (IFDC, 2007). The major N loss reduction results from negligible run-off loss as indicated by lower amounts of N in the flood water and lower ammonia volatilization loss. Urea deep placement (UDP) in flooded soil reduces nitrification (N fertilizer is deep placed in anaerobic soil); hence emission of NO and N_2O gases is reduced. Bhuiyan *et al.* (1988) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU. Similarly, Mohanty *et al.* (1999) reported that USG deep placement resulted in additional grain yield of 1080, 510 and 350 kg ha^{-1} over PU in alternate wetting and drying, shallow low land and intermediate low land, respectively. Wani *et al.* (1999) revealed that 120 kg N ha^{-1} as USG was the best in producing the yield and yield attributes of rice.
However, there is an ample need to find out the relative efficiency of different application methods of N-fertilizers on the performance of rice crop. Thus the present study was undertaken to find out the effect of different methods of application of urea fertilizer in Aman rice.

Objectives:

I. To assess the impact of different methods of urea application in Aman rice.

II. To select a suitable and economic method of urea application.

III. To verify the effect of USG on the growth and yield of Aman rice and to compare the effectiveness of USG with others applications.

CHAPTER II
LITERATURE REVIEW

Higher yield of rice can be obtained by applying suitable method of fertilizer. There are different forms of urea fertilizer. In this chapter an attempt has been made to present a review some of the recent available information related to the effect of USG, prilled urea (PU), foliar urea, broadcasting urea application method and spacing on the growth, yield and yield components of Aman rice.

Khatun *et al.* (2015) investigated the efficiency of BRRI prilled urea applicator, in a field experiment was conducted during *boro* season of 2013-2014 at the Bangladesh Rice Research Institute (BRRI) experimental farm, Gazipur and at farmer’s field of Dhirasshram village under Gazipur Sadar Upazilla, Gazipur, Bangladesh. Four treatments were hand broadcasting of prilled urea as per BRRI recommendation (T_1), prilled urea application by applicator (70% of the BRRI recommended dose) (T_2), hand broadcasting of prilled urea (70% of the BRRI recommended dose) (T_3) and N-control (T_4) were evaluated in the study. The T_2 treatment gave the highest grain yield of 6.96 $t{\cdot}ha^{-1}$ and 7.20 $t{\cdot}ha^{-1}$ at BRRI farm and Dhirasshram village, respectively, followed by the T_1 treatment. The highest agronomic use efficiency was obtained from T_2 treatment in both the locations. Similar scenario for apparent recovery efficiency, utilization efficiency and partial factor productivity was also observed in T_2 treatment. About 30% prilled urea was saved due to deep placement of urea by applicator in Boro season.

Sarker *et al.* (2015) conducted an experiment at BRRI research farm in Gazipur, during 2012 to evaluate the NPK briquette efficiency in rice production. Eight treatments were tested under each experiment. The tested varieties were BRRI dhan29 in Boro, BRRI dhan27 in T Aus and BRRI dhan49 in T Aman season. The results revealed that the deep placement of NPK briquette (2 x 2.4 g) increased about 10% yield and saved 37% N, 30% P, and 44% K than BRRI recommended rate of fertilizer in Boro season. Similarly, NPK briquette (1 x 3.4 g) produced 28% and 18% more rice yield over BRRI recommended rate of fertilizer for T Aus and T Aman season, respectively and also resulted in savings of 26-39% N. Deep placement of NPK briquette resulted in 4-10% higher rice yield and nutrient savings of 20-35 percent N, 18% percent P and 17-24% K over the recommended practice of NPK incorporation. Undiscounted benefit cost ratio (BCR) was 1.44, 2.40 and 3.20 for Boro, T Aus and T Aman seasons respectively when comparing at the same rates of N application. Thus, use of NPK briquette over NPK broadcast and incorporation was economically viable and efficient for rice cultivation.

Aziz and Hossain (2014) conducted an experiments at farmer's field, Alampur, Sylhet during T. aman season 2012 and Boro season 2013 in order to find out the suitable application method of USG (urea super granule) for wetland rice. Six treatment combinations were tested in T. aman season: T_1 = N –control (N0), T_2 = USG deep-placement @ 50 kg N/ha, T_3 = USG broadcast @ 50 kg N/ha, T_4 = USG deep-placement @ 75 kg N/ha, T_5 = USG broadcast @ 75 kg N/ha, T_6 = Prilled urea on STB (soil test based). Six treatment combinations were tested in Boro season: T_1 = N –control (N0), T_2 = USG deep-placement @ 75 kg N/ha, T_3 = USG broadcast @ 75 kg N/ha, T_4 = USG deep-placement @ 125 kg N/ha, T_5 = USG broadcast @ 125 kg N/ha, T_6 = Prilled urea on STB. The blanket doses of fertilizers were applied on STB. The sources of N, P, K & S were USG, triple super phosphate (TSP), muriate of potash (MP) and gypsum. Results showed that the treatment T_4 where USG was deep-placement produced the maximum yield and also found superior in terms of economic point of view.

Parvin *et al*. (2013) conducted an experiment at Bangladesh Agricultural University, Mymensingh to investigate the effect of weeding and foliar application of urea on the yield and yield components of Boro rice *cv*. BRRI dhan 29. The experiment included four weedings e.g. no weeding (W_0), one weeding (W_1), two weedings (W_2) and three weedings (W_3) and six methods of urea application viz. foliar spray @ 0, 60, 80,100 and 120 kg/ hand soil application @ 220 kg/ha. Three weedings produced the highest number of total tillers hill^{-1}, effective tillers hill^{-1} and grains panicle^{-1}, which eventually contributed to the highest grain yield in this treatment. The highest grain yield was obtained from five times foliar urea spray @ 100 kg ha^{-1}. This highest grain yield was the resultants effect of highest numbers of effective tillers hill^{-1}and grains panicle^{-1}in this treatment. The interaction of weeding and foliar application of urea also influenced grain yield of Boro rice *cv*. BRRI dhan29. The highest grain yield was obtained from the five times foliar spray of urea @ 100 kg/ha with three weedings regime.

Qurashi *et al.* (2013) carried out an experiment at Bangladesh Agricultural University, Mymensingh to evaluate the effect of urea super granule (USG) as a source of nitrogen on the yield and yield components of transplant Aman rice cv. BRRI dhan39, BRRI dhan46 and BINA dhan7. Five levels of N (viz., 0, 60, 120 kg ha^{-1} as prilled urea and 60 and 120 kg ha^{-1} as USG) were taken as experimental treatments. The highest grain yield (4.82 t ha^{-1}) was recorded in BINA dhan7 and the lowest one (4.30 t ha^{-1}) was recorded in BRRI dhan39. Nitrogen @ 120 kg ha^{-1} as USG performed the best among the treatments in respect of yield and yield components of rice. The highest grain yield (5.46t ha^{-1}) was obtained from BINA dhan7 with 120 kg N ha^{-1} as USG which was statistically identical with 60 kg N ha^{-1}as USG. A considerable amount (31.25%) of prilled urea (PU) nitrogen could be saved by using USG. It may be concluded that USG could be used as N management to achieve better nitrogen use efficiency in reducing N loss than the PU.

Kirttania *et al.* (2013) conducted an experiment at Bangladesh Agricultural University, Mymensingh during the period from July to December 2012 to observe the effect of variety, age of tiller seedling used for transplanting and nitrogen management on the yield performance of transplant Aman rice. The experiment consisted of two varieties viz. BRRI dhan49 and BRRI dhan51, two ages tiller seedling viz. 25- and 35-day old, five nitrogen management viz. control (no urea), application of prilled urea @ 215 kg ha^{-1} (1/2 at 15 DAT+1/2 at 30 DAT), prilled urea @ 215 kg ha^{-1} (1/3 at 15DAT+1/3 at 30DAT+1/3 at 45DAT), urea super granules (USG) 1.8 g and USG 2.7 g $four\text{-}hill^{-1}$ in every alternate row. The results revealed that higher plant characters, straw yield and harvest index were obtained from BRRI dhan49 compared to BRRI dhan51. Older seedlings (35-day old) produced higher grain yield to younger seedlings. The grain yield was highest in 35-day old tiller seedlings of BRRI dhan51 while fertilized with 1.8g USG. This value was lowest when 25-day old tiller seedlings of BRRI dhan51 were fertilized with prilled urea in two split applications. It may be concluded that 35-day tiller seedlings of BRRI dhan51 fertilized with USG 1.8 g $four\text{-}hill^{-1}$ could be used for achieving higher yield of transplant Aman rice.

Hasanuzzaman *et al.* (2013) conducted an experiment at Sher-e-Bangla Agricultural University, Dhaka during the period of November 2010 to May 2011 to study the influence of prilled urea and urea super granules on the growth and yield of hybrid rice Heera1. The treatments consisted of six prilled urea levels *viz.* 0, 80, 120, 160, 200 kg N ha^{-1} and urea super granule @ 75 kg N ha^{-1}). The effect of USG showed significant variation in respect of growth, yield contributing characters and yield. At harvest, the highest number of effective tillers $hill^{-1}$ (13.63), filled grains $panicle^{-1}$ (154.67), 1000- grain weight

(29.35 g), grain yield (9.42 t ha^{-1}) and straw yield (13.33 t ha^{-1}) were obtained from the application of USG showing 10% more grain yield than PU.

Xiang *et al.* (2013) conducted an experiment in International Rice Research Institute (IRRI) farm to examine the effect of different methods of nitrogen application on plant growth of aerobic rice grown in continuous aerobic rice system. The field micro-plot experiment showed that urea and urea super granules (USG) deep placement increased grain yield of aerobic rice by 1.66 t ha^{-1} in continuous aerobic rice cultivation. They also suggested that there was a possibility of improving aerobic rice yield in the continuous aerobic rice system by using right N source or changing conventional method of nitrogen application to deep placement.

Shah *et al.* (2013) carried out twelve experiments at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, BRRI regional station Sagordi, Barisal and farmers' field in 2012 to evaluate the NPK briquette efficacy in rice production. Experimental results revealed that deep placement of NPK briquette (2 x 2.4g) increased rice yield about 10 percent and it saved 37 percent N, 30 percent P and 44 percent K than BRRI fertilizer recommended rate in boro season. Similarly, NPK briquette (1 x 3.4g) produced 28 percent and 18 percent more rice yield than BRRI fertilizer recommended rate for T. Aus and T. Aman, respectively. Thus, use of NPK briquette over NPK broadcast and incorporation was very much efficient for rice cultivation.

Bhuyan *et al.* (2012) conducted an experiment on bed planting with urea super granule (USG) application of rice production systems to study the impact of granular urea application on growth and yield of transplanted Aman rice as well as evaluation of water and fertilizer use efficiency of rice-fallow-rice cropping system was investigated under raised bed cultivation method. Result showed that the USG in bed planting method increased grain yield of transplanted Aman rice up to 12.32% over prilled urea (PU) broadcasting in conventional method. The USG application in bed planting method increased the number of panicle m^{-2}, number of grains $panicle^{-1}$ and 1000-grains weight of rice than the PU in conventional method. Sterility percentage and weed infestation were lower at USG application in bed planting method than the PU in conventional method. Forty percent irrigation water and time for application could be saved through the USG in bed planting than the PU broadcasting in conventional method. Water use efficiency for grain and biomass production was higher by the USG application in bed planting than the PU broadcasting in conventional method. Likewise, agronomic efficiency of the USG in bed planting was higher than the PU broadcasting in conventional method. This study concluded that the USG in bed planting method was a new approach to get better fertilizer and water use efficiency as well as higher yield compared to the existing agronomic practice in the world.

Das *et al*. (2012) conducted an experiment at Mymensingh during December 2008 to May 2009 to evaluate the influence of spacing of transplanting and rate of urea super granules on the yield of Boro rice. The experiment consisted of two spacing of transplanting and three rates of urea super granules. The higher grain yield (4.46 t ha^{-1}) was obtained from 20 cm × 20 cm spacing. They also found that rates of urea super granules significantly influenced all the yield contributing characters except weight of 1000-grain and length of panicle. The maximum effective tillers $hill^{-1}$ (14.60), grains $panicle^{-1}$ (109.1), grain yield (5.80tha^{-1}) and harvest index (44.90%) were obtained from 2.7g USG (68 kg N ha^{-1}).

Azam *et al.* (2012) conducted a field experiment at the agronomy field of She-re-Bangla Agricultural University, Dhaka to find out the influence of variety and different urea fertilizer application method on growth and yield of boro rice. The experiment was carried out in split-plot design with three replication shaving three varieties. Result showed that variety and urea fertilizer application method had significant effect on plant height, tillers hill^{-1}, dry weight hill^{-1}, grains panicle^{-1}, leaf area index, 1000-grain weight, grain yield, straw yield and harvest index. Urea super granule treated plots showed better performance than that of prilled urea.

Miah *et al.* (2012) carried out a field experiment at Bangladesh Agricultural Development Corporation (BADC) Farm, Baradi, Meherpur during boro season to study the effects of two slow release nitrogenous fertilizer named prilled urea (PU) and urea super granule (USG) on growth, yield and quality of BRRI dhan28. There were ten treatment combinations consisting of two forms of urea *viz.,* PU and USG and five levels of each form (0, 110, 180, 240 and 300 kg ha^{-1}). Besides, TSP, MOP, gypsum and zinc sulphate were applied @ 100, 70, 60 and 5 kg ha^{-1}, respectively as basal dose. The highest grain yield (5.77 ton ha^{-1}) was found in USG_{240} and straw yield (12.11 ton ha^{-1}) was found in USG_{300} and the lowest grain (4.12 ton ha^{-1}) and straw yield (8.33 ton ha^{-1}) were found in control. The highest protein and starch contents were observed in USG_{300} treatment and lowest were found in control. A positive and significant correlation was found between grain yield and yield attributes in grain. The results suggest that urea super granule @ 240 kg ha^{-1} may be suitable for better growth and yield of Boro rice cv. BRRI dhan28 in the agro-climatic condition of the study area.

Yoseftabar (2012) compared the yield and yield components of hybrid rice (GRH1) in different application of nitrogen fertilizer, comprising of 2 treatments, nitrogen fertilizer at 100, 200 and 300 kg/ha was main plot and spilt application at 3 levels T_1=(1/2 basal-1/2 mid tillering), T_2=(1/3 basal-1/3mid tillering-1/3 panicle initiation) and T_3=(1/4 basal-1/4 mid tillering-1/4 panicle initation-1/4 flowering) as sub plot. The results showed that yield and yield components increased significantly with nitrogen fertilizer. Interesting in comparison to 100 and 200 kg ha^{-1} level application of higher N-fertilizer 300 kg/ha showed a positive respond to application of high nitrogen on hybrid cultivar. Study interaction effect of treatments revealed that all the yield and yield parameters increased significantly with an application of 300 kg ha^{-1} N-fertilizer at 4 stages.

Qian *et al.* (2011) evaluated the effects of organic manure application on rice yield soil in double-rice cropping region in south China. Five different treatments with mixed chemical and organic fertilizers, no fertilization (CK), N, P and K chemical fertilizers only (NPK), 70% chemical fertilizers and 30% organic manure (7OF + 30M), 50% chemical fertilizers and 50% organic manure (50F + 50M), and 30% chemical fertilizers and 70% organic manure (30F+ 70M) with their replications were examined. Results revealed that organic manure application combined with chemical fertilizers treatments were 65.4% -71.5% ($P<0.05$) higher than CK, and 3.9% - 7.8% ($P<0.05$) higher than NPK treatment in yield. Rice yield of 30F+70M treatment was the highest in all treatments.

Alam *et al.* (2010) studied the effect of soil and foliar application of urea on the yield and nutrient uptake of BRRI dhan 29 and to evaluate whether urea foliar application (FA) could replace its soil application (SA) in the rice cultivation. The experiment was laid out in a randomized complete block design (RCBD) with eight treatments, each treatment replicated thrice. The treatment T_2 (282 kg urea ha^{-1}) produced the highest grain yield (5.34 t ha^{-1}). The T_6 (94 kg urea ha^{-1} + 1% urea solution FA) produced the highest straw yield (6.58 t ha^{-1}) of the crop. The lowest grain yield (3.20 t ha^{-1}) and the lowest straw yield (4.19 t ha^{-1}) were recorded with T_1 (control). Economic analysis showed that treatment T_2 gave the highest marginal benefit cost ratio (7.65) while the lowest value (2.71) was observed with T_5 treatment. The overall results demonstrated that soil application of 282 kg urea ha^{-1} was the best treatment for obtaining higher grain yield, higher nitrogen content of rice and higher marginal benefit cost ratio, and soil application was better than foliar application of urea.

Islam *et al.* (2009) determined that split application of urea fertilizers significantly increased the plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf area hill^{-1} (cm^2), DM (dry matter) of root, stem and leaves hill^{-1}, TDM (total dry matter) hill^{-1} and chlorophyll content in leaves (at 74 DAT). Consequently, the crop fertilized with 215 kg urea ha^{-1} applied at three equal split at 15, 30 and 55DAT gave maximum grain yield.

Choudhury *et al.* (2009) conducted a field experiment at Bangladesh Rice Research Institute to evaluate the effect of urea super granule (USG) deep point placement compared to conventional prilled urea (PU) broadcasting with respect to yield and nitrogen nutrition of wetland rice (Variety BR11). The result showed that USG treated plots gave higher grain and straw yields compared to PU treated plots within same dose of added N. In addition to that total N uptake by BR11, agronomic efficiency and apparent recovery of added N were also higher with USG compared to PU within the same N dose.

Zhang *et al.* (2008) identified an effective fertilizing scheme for direct-seeding rice (DSR) fields in the Taihu Lake Basin in east China. Based on local traditions, 3 typical fertilizing schemes (FS-1, FS-2, and FS-3) were evaluated, in consideration of ensuring a certain rice yield and relatively low nitrogen (N) loss. The base, seedling, tillering, jointing, and panicle fertilizers for FS-1 were all 20% of 270 kg N ha^{-1}, those for FS-2 were 30%, 30%, 0%, 25%,and 15% of 270 kg N ha^{-1}, and 15%, 20%, 25%, 20%, and 20% of 220 kg N ha^{-1} for FS-3, respectively. The results show that the majority of fertilizer N for DSR should be applied as topdressing fertilizer and not as base fertilizer as in transplanted rice cultivation. Increasing base fertilizer would not significantly improve the growth or yield of rice due to the low uptake of N during the seedling stage, and in turn would lead to greater N loss. Under FS-1, FS-2, and FS-3, N loss was 91.4, 103.1, and 70.5 kg ha^{-1}, respectively, via surface runoff, volatilization, and leaching. Furthermore, using different fertilizer N methods during the rice growing season led to different N uptake by rice plants. In the present study N uptake by rice was measured at 108, 91, and 102 kg N ha^{-1} under FS-1, FS-2, and FS-3, respectively. At the same time, the rice yield with FS-1, FS-2, and FS-3 was 8530, 7780, and 8620 kg ha^{-1}, respectively. As a result, FS-3 was used in this study for DSR cultivation in the Taihu Lake Basin, which resulted in good rice yield and totally reducing N loss of 20.9-32.6 kg ha^{-1}.

Kapoor *et al.* (2008) evaluated the influence of deep point placement of N, P and K briquettes compared to broadcast in corporation of N, P and K on floodwater nutrient loads after fertilizer application. They found that broadcast application of N as urea resulted in an average 10 times higher amount of ammonium N (NH_4-N) in flood water compared to deep placement of urea briquette and single superphosphate resulted in 67 times higher amounts of P in floodwater than plots receiving deep placed P. The flood water NH_4-N, P and K content in the deep placement treatments were negligible-similar to floodwater N, P and K content without fertilizer application.

Hach and Nam (2006) conducted a field experiment at the Cuu Long Delta Rice Research (CLRRI) farm in 2004 in wet and dry seasons to evaluate the responses of some promising high yielding rice varieties to nitrogen fertilizers. The results of the study showed that application of nitrogen fertilizer at 60 kg N ha^{-1} obtained the highest economical efficiency of nitrogen applied (EENA) in the wet season for all tested rice varieties. Further increase in the rate of nitrogen fertilizer beyond 90kg N ha^{-1} gave a negative EENA value. In the dry season, at 80 kg N ha^{-1}, EENA obtained the highest for all tested rice varieties. At higher nitrogen rates (120-160 kg N ha^{-1}), EENA values were the lowest.

Chaturvedi (2005) studied the effect of different nitrogenous (N) fertilizers on growth, yield and quality of hybrid rice variety ‘Proagro 6207’, comprising of 10 different treatments using randomized complete block design with three replications was conducted at Agricultural Research Station, Bilaspur Chhattisgarh, India. The two years data during 2002 and 2003 revealed that all the growth characters, yield parameters and grain nitrogen (N) increased significantly with an application of sulphur-containing nitrogen fertilizer- Super Net. These results were statistically showed that of treatment T_4, where ammonium sulphate nitrate was applied. In this series of experiment, non-sulphur-containing nitrogen fertilizer, urea gave lowest yield and grain nitrogen (N) content and these reductions were significant in all of the experiments.

Mashkar and Thorat (2005) conducted a field experiment during the 1994 kharif season in Konkan, Maharashtra, India, to study the effects of different nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}) on the N, P and K uptake and grain yield of scented rice cultivars (Pusa, Basmati 1, Kasturi, Indrayani and Sugandha). The different levels of N had significant effect in augmenting the uptake of N, P and K nutrients and grains as well as straw yield of rice. Application of 120 kg N ha^{-1} recorded significantly higher N, P and K uptake inrice compared to the rest of the N levels. Every increment of 40 kg N ha^{-1} from 0 to 120 kg N ha^{-1} increased the total N uptake by 49.55, 34.30 and 27.17% total P uptake by 40.33, 27.06 and 20.32% and total K-uptake by 32.43, 20.70 and 17.25% respectively.

Rahman *et al.* (2005) determined the nitrogen level and found that the grain yield of rice increased with increasing N levels and the highest yield (4.19 t ha^{-1}) was attained with 150 kg N ha^{-1} while further increase in nitrogen level decreased the grain yield. It was estimated that the grain yield with 150 kg Nha^{-1} was 35.8, 18.9, 5.0 and 6.0% higher than those obtained with 0, 50, 100 and200 kg N ha^{-1} respectively.

Kulkarni *et al.* (2005) carried out a field experiment at an agricultural college farm in Kolhapur, Maharashtra, India to investigate the utilization of prilled urea (PU) and urea super granules (USG) in single and split doses by deep placement at different crop growth stages. Grain yield was significantly increased by PU and USG application over control (no nitrogen). Treatments with 100 kg USG N, 80 kg USG N and 100 kg prilled urea N ha^{-1} in single and split doses were applied. Rain fed rice showed good performance under N application through USG at 80 kg N ha^{-1} and 100 kg N ha^{-1} as full basal dose by deep placement.

Sidhu *et al.* (2004) evaluated that nitrogen fertilizers substantially increased the mean grain yield of Basmati up to 40 kg N ha^{-1} in the fallow Basmati-wheat sequence while 60 kg N ha^{-1} reduced Basmati yield. Compared to the treatmentno, the mean grain yield of Basmati was increased by 0.31, 0.40 t ha^{-1} at doses of 20 and 40 kg N ha^{-1}, respectively.

Hossain *et al.* (2004) carried out an experiment at the farm of Bangladesh Institute of Nuclear Agriculture (BINA) to see the effect of four levels of seedling $hill^{-1}$ viz., 1, 2, 3 and 4 and two forms of nitrogen fertilizer- prilled urea (PU) and urea super granule (USG) on growth, yield and yield components of transplanted Bina dhan-4. The results showed that most of the growth parameters at all levels of seedling $hill^{-1}$ gave higher values with USG than those with PU. The highest grain yield (5.71 t ha^{-1}) and straw yield (8.20 t ha^{-1}) was obtained due to application USG.

Wang (2004) studied the effect of deep placement of fertilizer and nitrogen top dressing on rice yield and to develop a simple method for diagnosing the level of nitrogen (N) top-dressing during panicle initiation stage. The deep placement of nitrogen fertilizer promoted nitrogen uptake, grain nitrogen and nitrogen harvest index, resulted in a higher dry matter production, harvest index and a higher grain yield of rice plant compared with conventional nitrogen application. Similarly, top dressing of nitrogen at panicle initiation stage also increased nitrogen uptake, dry matter production, nitrogen harvest index, and harvest index and grain yield of rice plants.

Dongarwar *et al*. (2003) conducted a field experiment in Bhandara, India to investigate rice ($KJTRH^{-1}$) in comparison with 2 conventional cultivars, Jaya and Swarna, to 4 fertilizer rates i.e. 75, 100, 125 and 150 kg N ha^{-1}. There was a significant increase in grain yield with successive increase in fertilizer rate. The highest grain yield (53.05 q ha^{-1}) was obtained with 150 kg N ha^{-1} and $KJJRH^{-1}$ produced a significantly higher yield than Jaya (39.64 q ha^{-1}) and Swarna (16.06 q ha^{-1}).

Obiol *et al.* (2003) studied the effect of different nitrogen doses on the yield and yield components of rice varieties (IA Cuba-17, IA Cuba-24 and J-104). Nitrogen was applied at 0, 43, 85, 128, 170and 215 kg ha^{-1}. Improved response was obtained with 128-170 kg N ha^{-1}.

Duhan and Singh (2002) found that the rice yield and uptake of nutrient increased significantly with increasing N levels. Moreover, the application of N along with various green manures (GM) showed additive effects on the yield and uptake of micronutrients. Under all

GM treatments the yield and nutrient uptake were always higher with 120 kg N ha^{-1} than with lower level of nitrogen.

Zhang and Wang (2002) studied on the agronomic performance of a newly developed site specific nutrient management (SSNM)technique for nitrogen fertilizer application to directly sown early rice against farmers fertilizer practice (FFM) in Jinhua, Zhejiang, China. Results showed that SSNN increased the rice yield significantly and improves N use efficiency substantially.

Angayarkanni and Ravichandran (2001) conducted a field experiment in Tamil Nadu, India from July to October 1997 to determine the best split application of150 kg N ha^{-1} for rice cv. IR 20. They found that applying 16.66% of the recommended N as basal, followed by 33.33% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT recorded the highest grain (6189 kg ha-1) and straw (8649kg ha^{-1}) yields, response ratio (23.40) and agronomic efficiency (41.26).

Ahmed *et al*. (2000) revealed that USG was more efficient than PU at all level so nitrogen 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}) 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 nitrogen.

Russo (1996) compared the effects of slow-release N-fertilizers (ISODUR) and products integrated with diciandiamide (DCD), a nitrification inhibitor, with the N splitting method applied in two or three times on the rice growth and yield. The effect of increasing N rate at preplant time compared with the top dressing application was also determined. Experiments were conducted for 2 years on a typical Po Valley sandy soil. Fertilizers treatments were applied on two commercial rice cultivars, Baldoand Panda, using a split-plot design.

Fertilizer treatments replicated four times were main plots; and cultivars were subplots. Different types of N fertilizers through two years experiments were compared with N split applications based on two or three times. Plant growth (height), plant development (days to heading and ripening), rice yield, yield components, and quality were monitored. Results showed that split fertilization with N top dressed at panicle initiation stage was more effective in rice yielding than preplant only application, independently from the N rate. Commercial “slow-release” fertilizer and ammonium sulphate were less effective in rice production. Compared to urea, inhibitor of nitrification, Diciandiammide (DCD) was the top yielding treatment, when applied with the split method. The fertilization method, based on three split N applications, showed no significant yielding differences compared to the two times method.

CHAPTER III

METERIALS AND METHODS

This chapter deals with a brief description on experimental period, experimental site, climate, soil, and land preparation, layout of the experimental design, intercultural operations, data recording and their analysis. Details of materials and methods used in this experiment are given below:

3.1 Required Apparatus:

The application method of urea in the fields depends on the types of urea fertilizer. The following machineries are used in this experiment:

1. BRRI USG (urea super granules) applicator
2. BRRI Prilled urea applicator
3. Knapsack sprayer

3.1.1 USG (urea super granules) applicator

Before the field operation, the adjustment of USG applicator was done considering the line to line distance of transplanted rice. Desired amount of Urea Super Granule (USG) kept in the applicator hopper. The USG applicator drives between two rows in a single passing. The operator operates the applicator by pushing force. During operation, handle height was also adjusted in such a way that the operator feels comfort to operate the applicator and covering device remain in contact with the soil horizontally. After one revolution of drive wheel urea super granules dispensed from both the hoppers in 8-10 cm depth between 4 hills at alternate rows.

Fig-3.1: BRRI USG applicator

3.1.2 Prilled urea applicator

Before the field operation, the adjustment of prilled urea applicator was done considering the line to line distance of transplanted rice. Desired amount of prilled urea kept in the applicator hopper. The prilled urea applicator drives between two rows in a single passing. The operator operates the applicator by pushing force. During operation, handle height was also adjusted in such a way that the operator feels comfort to operate the applicator and covering device remain in contact with the soil horizontally. After one revolution of drive wheel 7-9 gm of prilled urea dispensed from both the hoppers in 8-10 cm depth among 4 hills in alternate rows.

Fig-3.2: BRRI Prilled urea applicator

3.1.3 Knapsack sprayer

Knapsack sprayer is widely used in agriculture. The World Health Organization (WHO) has produced detailed specifications of spraying equipment suitable for residual wall-spraying in order to ensure uniform and safe application of insecticides. This is carried on the back. A frame or shield prevents contact between the tank and the back. It is a continuous type of sprayer with a fairly constant discharge rate. The operator maintains pressure in the tank by pumping air with a lever with one hand and directs the spray lance with the other. If the sprayer is fitted with a spray control valve, continuous pumping may not be necessary. In this experiment, Knapsack sprayer is used for the control of agricultural pest and foliar application of urea.

Fig-3.3: Knapsack sprayer

Working Procedure:

The experimental details are described below under different sub-heads:

3.2. Description of the experimental site

Location

The experiment was conducted at Hajee Mohammad Danesh Science & Technology University (HSTU) Farm, Dinajpur during aman season of 2016 (June-November). Geographically, the experimental area is located latitude at 25^0 37'16"N and 88°38' 4" E longitude at the elevation of above 37.50 m the sea level.

Soil

The experimental land was characterized by non calcareous brown floodplain soil. The land was well drained and medium high with sandy loam soil having pH value of 4.72. The characteristics of the soil have been presented in Appendix I.

Climate & Weather

The experimental area has sub-tropical climate which is characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds in Kharif season (16 March - 15 October) and scantly rainfall associated with moderately low temperature during Rabi season (16 October - 15 March).

3.3 Plant material

Aman rice variety Binadhan-7 was used as the test crop. This variety was selected for the experiment because of its short duration and fine grains could be planted in relatively low land area.

3.4 Description of Urea Super Granules

USG fertilizer is manufactured by physical modification of ordinary urea fertilizer. It has been developed by the International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama 35660, USA. There are two sizes of USG recommended by IFDC for rice cultivation in Bangladesh. For Aus and Aman rice the USG sige is 1.8g and for boro rice the size of USG is 2.7g. Its nature & properties are similar to that of urea. But its granule size is bigger and condensed with some conditions for slow hydrolysis. USG is spherical in shape containing 46% N, which is similar to that of PU. It is not a slow-release fertilizer but can be considered as a slowly available N fertilizer.

3.5 Land preparation

The experimental land was prepared by ploughing with power tiller. The land was then puddled thoroughly by repeated ploughing and cross ploughing and subsequently leveled by laddering. All kinds of weeds and stubbles were removed from the field before final ploughing and leveling.

3.6 Treatments:

Treatments included in the experiment were as follows:

T_1 = 194 kg/ ha urea at two equal splits (Conventional)

T_2 = Urea Super Granules @ 81.5 kg/ha (Only once)

T_3 = 2% foliar spray solution @ 45 kg/ha (Three times)

T_4 = Prilled urea 138 kg/ha (Only once)

3.7 Layout of the experiment

The experiment was laid out on 01 August 2016 in a randomized complete block design (RCBD), where the experimental area was divided into 3 blocks representing the replications to reduce the heterogenic effects of soil. There were 4 different treatment combinations. Each block was subdivided into 4 plots and the treatments were randomly distributed to the unit plots in each block. Thus the total number of unit plot was 12. The size of each plot was 4 m x 3 m and plots were separated from each other by ails. There was 30 cm drain between the blocks that separated the blocks from each other.

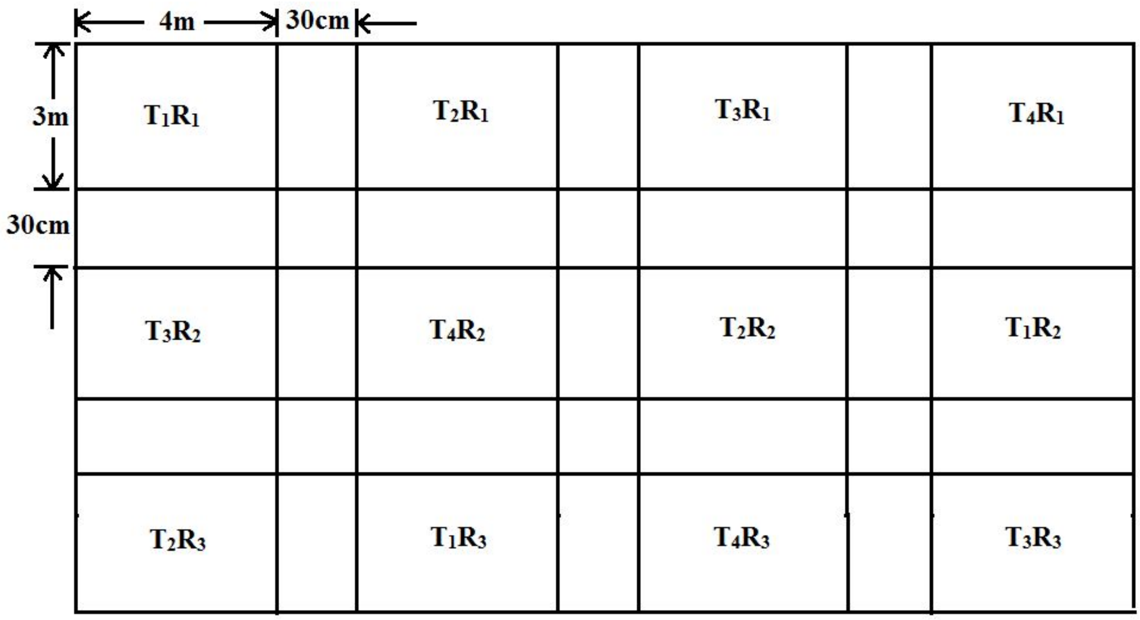

Fig-3.4: Layout of RCBD (Randomized Complete Block Design).

3.8 Transplanting of seedling

Thirty-five days old seedlings were carefully uprooted from a seedling nursery bed and transplanted in the plots on 02 August 2016 in the main field at the rate of three seedlings $hill^{-1}$ by maintaining a spacing of 15 cm x 20 cm.

3.9 Application of fertilizers

The land was fertilized as per treatment layout. The amount of phosphorus, sulphur and zinc required for total land was calculated on hectare basis in accordance with standard specifications and applied in the form of triple superphosphate, muriate of potash, gypsum and zinc sulphate at the rate of 148-178-100-15 kg ha^{-1} respectively. Full dose of triple superphosphate, muriate of potash, gypsum and zinc sulphate were applied at the time of final land preparation in the respective unit plots. Urea was applied in two equal spilts.The first spilt of urea was top dressed after 11 days of transplanting and the second spilt of urea was top dressed after 33 days of transplanting (panicle initiation stage). As per experimental specification USG were placed at 8-10 cm depth after 7 days of transplanting in the centre of four hills in alternate rows. In the same process prilled urea was also applied in the centre of four hills. Foliar urea was also applied in three equal spilts. The first spilt of foliar urea was sprayed after 9 days of transplanting, the second spilt of foliar urea was sprayed after 24 days of transplanting and the third spilt of foliar urea was sprayed after 41 days of transplanting.

Fig-3.5: Application of fertilizers in different methods

3.10 Intercultural operations

Intercultural operations were done as and when necessary for ensuring and maintaining the favourable environment for normal growth and development of crop. The following operations were performed:

3.10.1 Gap filling

Seedlings in some hills died off and these were replaced by gap filling after one week of transplanting with healthy seedlings from the same source.

3.10.2 Irrigation

Natural precipitation was not found adequate. For this reason irrigation was provided to the plots from shallow tube well to maintain continuous flooding condition during the growing period of the crop.

3.10.3 Weeding

The experimental plots were infested with some obnoxious weeds, which were controlled by uprooting and removing as many as three times from the field.

3.10.4 Pesticide Application

Cyperfos (chlorpyrifos 50% + cypermithrin 5% 1ml/l) pesticide was applied three times for protecting Stem Borer (*Scripophagaincertulas*) and Semco (Atropinsulphate + PAM) was applied for False Smut (*UstilaginoideaVirens*).

3.11 Harvesting

Harvesting was done depending at the full maturity of crop. Maturity of crop was determined when 90% of the grain becomes golden yellow in colour. Randomly three

Fig-3.6: Harvesting of ripen crops.

places of each plot were harvested having area $0.36m^2$ to record the yields of grain and straw. After sampling, the whole plot was harvested at maturity. Binadhan-7 was harvested on 03 November 2016. The harvested crops of each plot was separately bundled, properly tagged and then brought to threshing floor. Threshing was done manually. The grains were cleaned and sun dried to moisture content of 14%. Straws were also dried properly. Finally grain and straw yield $plot^{-1}$ were recorded and converted to ton ha^{-1}.

3.12 Data collection

The following data on yield components and yield were recorded.

I. Plant height(cm)
II. Number of total tillers $hill^{-1}$
III. Panicle length(cm)
IV. Number of grains $panicle^{-1}$
V. Weight of 1000 grains(gm)

VI. Grain yield (t ha^{-1})
VII. Straw yield (t ha^{-1})
VIII. Biological yield (t ha^{-1})
IX. Harvest Index (%).

Data on individual plant parameters were recorded from five randomly selected hills of each plot excluding border rows and those on seed moisture percentage, grain yield, straw yield, biological yield and harvest index were recorded from the whole plot at harvest.

3.13 Procedure of data collection

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

3.13.1 Growth measurement at different days after transplanting

Panicle length

The measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 hills.

Plant height

The plant height was measured three times from the ground level to the top of the plant at 15 days interval beginning at 15 DAT to 75 DAT. From each plot, heights of 5 hills were measured and averaged.

Fig-3.7: Plant height measurement

Number of total tillers hill^{-1}

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

Number of grains panicle^{-1}

Five panicles were taken at random hill^{-1} and the filled grains panicle^{-1} were counted and averaged.

Weight of 1000 grains (gm)

1000-grains were taken from the collected samples treatment wise and the weight was recorded in an electrical balance after sun drying.

Grain yield (t ha^{-1})

Grains obtained from each plot were sun dried, cleaned, weighed carefully. Dry weight of grams of each plot was converted into t ha^{-1}.

Straw yield (t ha^{-1})

Straw obtained from each plot were sun dried, cleaned, weighed separately and finally converted into t ha^{-1}.

Biological yield (t ha^{-1})

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

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

Harvest Index (%).

It is the ratio of grain yield to biological yield and was calculated with the following formula:

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

Cost Production Ratio:

It is the ratio of cost of urea application to the total price of paddy and was calculated with the following formula:

$$\text{Cost Production Ratio} = \frac{\text{Cost of urea}}{\text{Total price of paddy}}$$

3.14 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using a computer package program namely, SPSS.

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CHAPTER IV

RESULTS AND DISCUSSION

Result obtained from the study of nitrogen sources on growth and yield of Aman rice have been presented and discussed in this chapter. Treatments effect of nitrogen on all the studied parameters have been presented in various tables and figures and discussed below under the following sub-headings.

4.1 Yield Contributing Characters

The yield contributing characters such as plant height, number of tillers hill^{-1}, panicle length and number of grains panicle^{-1}, 1000-grain weight of Binadhan-7 responded significantly to the treatments as shown in Table-1 and also the grain and straw yield responded significantly to the treatments as shown in Table-2.

Table-1: Effect of different methods of urea fertilizer application on the yield contributing characters.

Treatments	Plant height (cm)	No. of panicles hill^{-1}	Panicle length (cm)	No. of grain panicle^{-1}	1000 grain weight (gm)
T_1	79.89±0.60^{bc}	18.11±1.26^{b}	21.61±.25^{c}	143.66±1.85^{b}	23.54±0.24^{b}
T_2	82.07±0.34^{a}	21.66±5.03^{a}	24.22±1.01^{a}	149.33±1.85^{a}	24.42±0.17^{a}
T_3	79.02±0.24^{c}	17.33±2.02^{c}	24.22±0.10^{a}	121.33±1.85^{c}	22.57±0.15^{c}
T_4	81.13±1.22^{ab}	17.55±0.50^{c}	22.22±0.34^{b}	149.20±1.7^{a}	24.28±0.11^{a}

*Means separation in columns followed by the same letter(s) are not significantly different at P=0.05.

4.1.1. Plant Height

Growth of rice plant was greatly influenced by different methods of application of urea fertilizer. In this study, plant height was significantly affected by urea application methods as shown in fig-4.1 and table-1. At all the growth stage (25, 50, 90 DAT), maximum plant height was observed with T_2 (Urea Super Granules@ 81.5 kg ha^{-1}). Maximum influences of urea fertilizer application methods were observed at 50 DAT because in this stage crop growth was highest. At maturity (90 DAT) the highest plant height was 82.07 cm with treatment T_2 which is 2.73% higher than the plant height obtained from treatment T_1 (194 kg ha^{-1} urea at two equal splits) from Table-1. At maturity T_2 and T_4 showed statistically similar results. The lowest plant height with treatment T_3 (2% foliar spray @ 45 kg ha^{-1}) might be due to reduced uptake of N through foliage. Application of granular urea at higher rate facilitated higher vegetative growth and hence maximum plant height attained. This result was supported by Islam et al (2009).

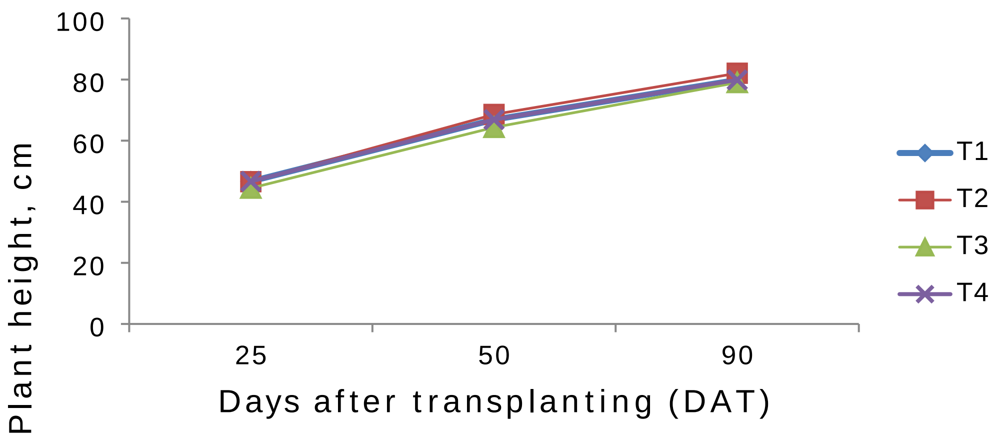

Fig-4.1: Effect of different methods of urea application on plant height

4.1.2. Number of Panicle per Hill

Application methods of urea significantly influenced the yield contributing characters ofBINA-7. Highest number of panicles per hill was observed with T_2(Urea Super Granules @ 81.5 kg ha^{-1}) which was 19.6% higher than number of panicles per hill obtained from T_1(194 kg ha^{-1} urea at two equal splits) as shown in fig-4.2. Lowest number of panicles per hill was observed with treatment T_3 (2% foliar spray @ 45 kg ha^{-1}) which was due to less amount of N uptake by plants, but there was no statistically significant difference between the treatments as shown in Table-1.

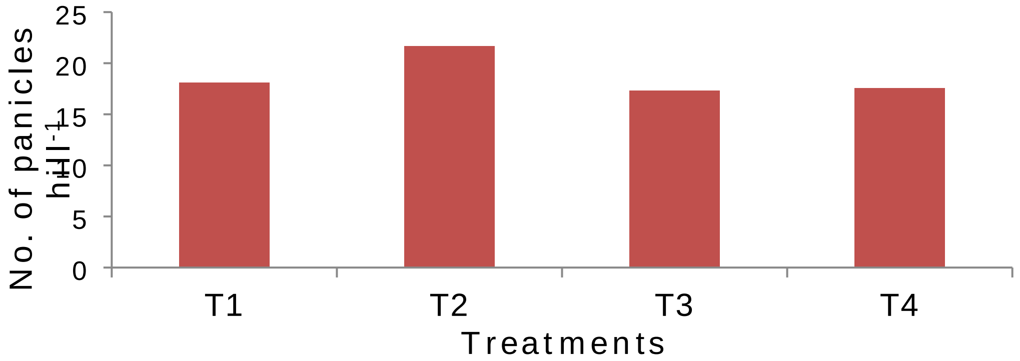

Fig-4.2: Effect of different methods of urea application on number of panicle hill^{-1}

4.1.3. Panicle Length

The treatment T_2also produced the longest panicle (24.22 cm) which was statistically similar as treatment T_3 and superior to other treatments (T_1 and T_2) as shown in table-1. Urea applied as super granules released nitrogen slowly which ensures sufficient N at panicle formation stage that confers the better results. This result was corroborated with the findings of Sen and Pandey (1990). Lowest panicles length was observed with treatment T_1 (21.61 cm) as shown in the fig-4.3.

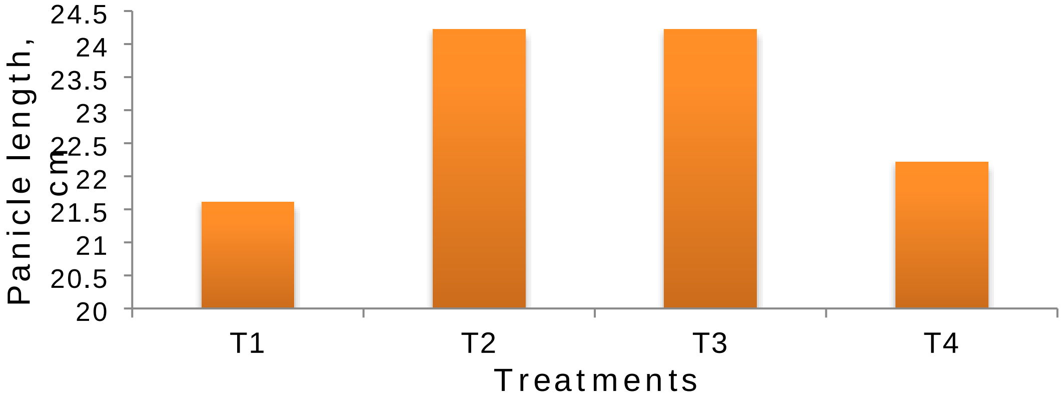

Fig-4.3: Effect of different methods of urea application on panicle length

4.1.4. Number of Grain per Panicles

The methods of application of urea fertilizer have significant effect on number grain per panicles of rice. In this study highest number of grain per panicles was observed with treatment T_2 (149.33 grain panicle^{-1}) which was statistically similar with treatment T_4 but superior to other treatments (T_1 and T_3) as shown in table-1. Lowest number of grain per panicles was observed with treatment T_3 (121.33 grain panicle^{-1}) as shown in fig-4.4 which was due to less amount and slow uptake of N in the grain formation stage.

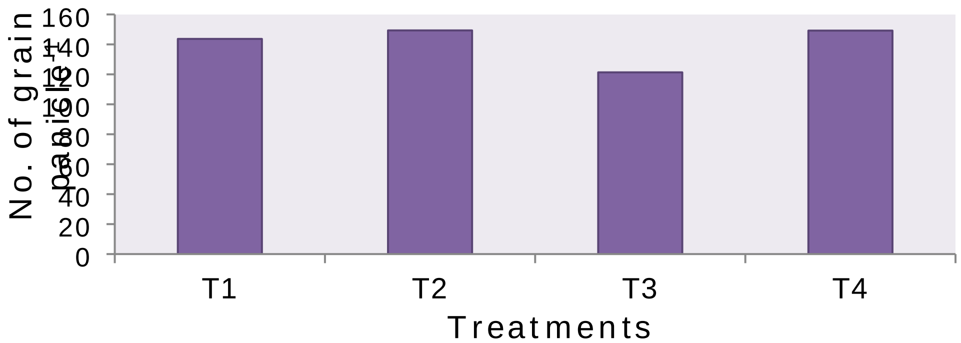

Fig-4.4: Effect of different methods of urea application on number of grain panicle^{-1}

4.1.5. 1000-Grain Weight

100 Grain weight was also highest (24.42 gm) with the treatment T_2 which was statistically similar with treatment T_4 as shown in table-1. Lowest grain weight was observed with treatment T_3 (22.57 gm) as shown in fig-4.5.

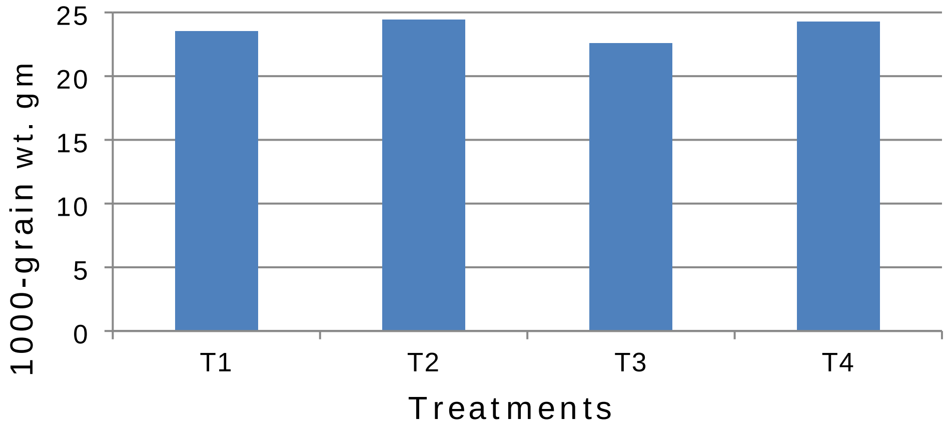

Fig-4.5: Effect of different methods of urea application on thousands grain weight

It showed that application of USG produced more yield components compared to other methods of urea fertilizer application.

4.2. Grain and Straw Yield

Both the grain yield and straw yield of Binadhan-7 was significantly influenced by different application methods of urea fertilizer as shown in Table-2 and Fig-4.6.

Table-2: Effect of different methods of urea fertilizer application on the grain yield and straw yield.

Treatments	Grain Yield		Straw yield	
	t ha^{-1}	% increase or decreased over T_1	t ha^{-1}	% increase or decreased over T_1
T_1	2.99^{bc}	-	7.71^{c}	-
T_2	3.42^{a}	14.38(+)	9.26^{a}	20.10(+)
T_3	2.68^{c}	10.36(-)	7.84^{c}	4.04(+)
T_4	3.18^{bc}	6.35(+)	8.48^{b}	9.98(+)
$LSD_{0.05}$	0.06		0.62	

*Means separation in columns followed by the same letter(s) are not significantly different at P=0.05.
** The sign plus (+) means increased and minus (-) means yield decreased.

In this study, the highest grain yield (3.42 t ha^{-1}) was observed from T_2 (Urea Super Granules @ 81.5 kg ha^{-1}) which was statistically similar with grain yield obtained from treatment T_1 and T_4. The lowest grain yield (2.68 t ha^{-1}) was observed with treatments T_3 (2% foliar spray @ 45 kg ha^{-1}) which was statistically different from other treatments. The grain yields due to different treatments may be ranked in the order of $T_2 > T_4 > T_1 > T_3$ as shown in the figure-4.6. From the table-2 we can see that treatment T_2 and T_4 produced 14.38% and 6.35% higher grain yield than traditional method T_1 (194 kg ha^{-1} urea at two equal splits) respectively and on the other hand treatment T_3 produced 10.36% lower grain yield than the traditional methods of urea application. Deep placement of urea produced highest yield by reducing the adverse effects of urea, this is because deep placement of urea can reduce nitrogen loss by ammonia volatilization. It was observed that urea super granules (USG) can minimize the loss of N from soil and hence the affectivity increased up to 20-25% (BRRI, 2008)

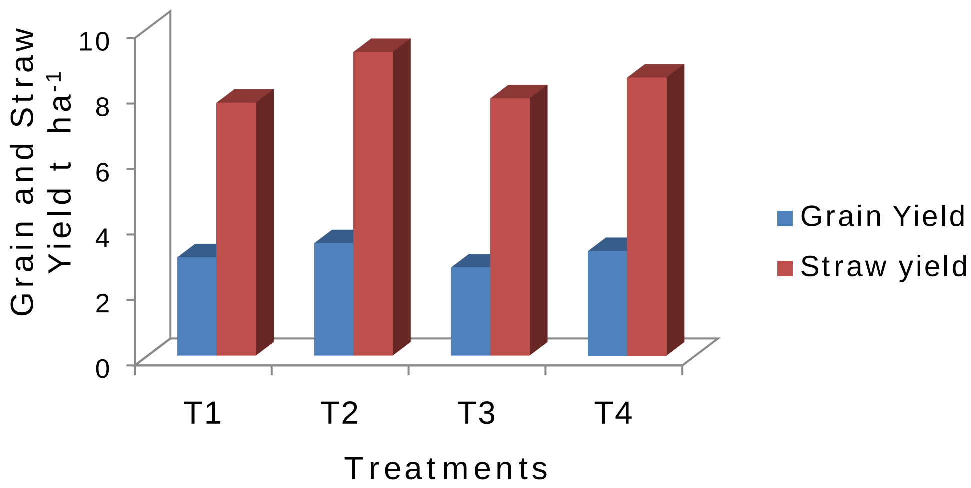

Fig-4.6: Effect of different methods of urea fertilizer application on the grain yield and straw yield

Straw yield also significantly affected by different methods of application of urea fertilizer as shown on the table-2. In this study, the highest straw yield (9.26 t ha^{-1}) was observed from T_2 (Urea Super Granules @ 81.5 kg ha^{-1}) which was statistically different from straw yield obtained from other treatment T_1, T_3 and T_4. It was due to more vegetative growth at maximum vegetative stage as influenced by granular urea application. With USG application more photosynthesis was trans-located to grain compared to straw (Sen *et al.,* 1990). The lowest straw yield (7.71 t ha^{-1}) was observed with treatments T_1 which was statistically different from treatments T_2 and T_4 but similar to treatments T_3. The straw yields due to different treatments may be ranked in the order of $T_2 > T_4 > T_3 > T_1$ as shown in the figure-4.6. From the table-2 we can see that treatment T_2, T_3 and T_4 produced 20.10%, 4.04% and 9.98% higher straw yield than traditional method T_1 (194 kg ha^{-1} urea at two equal splits) respectively.

4.3. Cost Production Ratio (CPR)

The costs of urea and production ratio data are shown in the table-3:

Table-3: Cost and production ratio

Treatment	Amount of urea applied ha^{-1}	Cost of urea fertilizer, ha^{-1} (Tk)	Yield (t ha^{-1})	Paddy price (Tk)	CPR	Cost of urea for paddy production, (TkKg^{-1})
T_1	190	3800	2.99	59800	15.73	1.27
T_2	81.5	1630	3.42	68400	41.96	0.47
T_3	45	765	2.68	53600	70.06	0.28
T_4	138	2346	3.18	63600	27.10	0.74

From table-3, it was seen that the cost of urea application was lowest for treatment T_3 also cost production ratio (CPR) was highest at that treatment. On the other hand, the highest cost of urea application was found for treatment $T_1$and also the cost production ratio (CPR) was lowest for that treatment. The cost production ratio due to different treatment may be ranked in the order of $T_3 > T_2 > T_4 > T_1$ as shown in the fig-4.7. It was also seen that the cost of per kg paddy production was highest at treatment T_1 and lowest at treatment T_3.

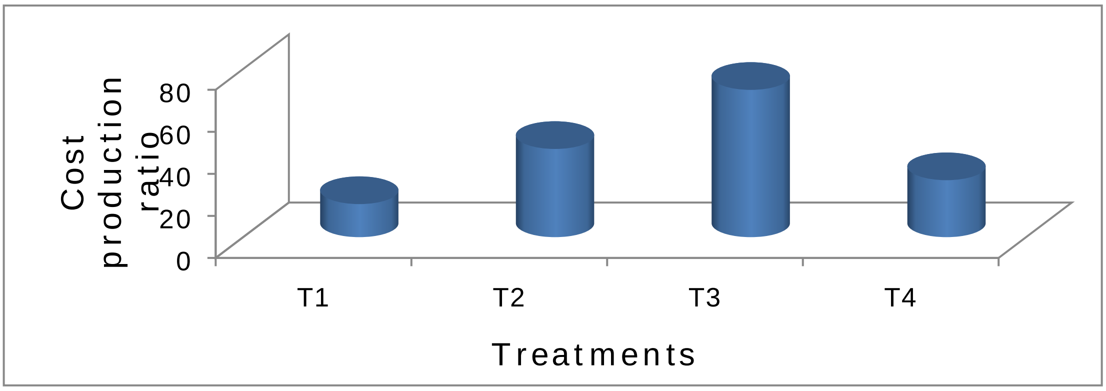

Fig-4.7: Cost production ratio (CPR)

Another cost items such as land rent, land preparation cost of seedlings, labour cost, pesticides cost were almost same for all treatments. That's why these cost items were not included with fertilizers cost. Though cost production ratio was highest of treatment T_3 but compare with the other yield contributing factors treatment T_2 may be recommended for farmers.

CHAPTER 5

SUMMARY AND CONCLUSION

This research work was carried out at the Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, from August to November 2016 in order to find the effect of USG, PU, foliar urea and broadcast urea on the growth, yield and yield components of transplant Aman rice cv. Binadhan-7. The soil was sandy loam in texture having pH 4.72, organic matter content 1.64%, total N 0.08%, available P 55.96 ppm, exchangeable K 0.21 me q 100 g^{-1} soil, available S 19.75 ppm. The experiment consisted of the four treatments viz. T_1= 194 kg/ ha urea at two equal splits, T_2= Urea Super Granules @ 81.5 kg/ha (Only once), T_3= 2% foliar spray solution @ 45 kg/ha (Three times), T_4= Prilled urea 138kg/ha (Only once). The experiment was laid out in a randomized complete block design with three replications. The size of each unit plot was 4.0 m × 3.0 m.

All experiment plots were prepared by ploughing and cross ploughing with power tiller as per treatment. All kinds of weeds and stubble were cleaned off from individual's plots and finally plots were leveled by laddering so properly by wooden plank that no water pocket could remain in the puddle field. Full dose of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at the time of final land preparation in the unit plots. Thirty five days old seedlings were transplanted on 02 August 2016 on the well puddled plots in the main field according to the experimental design at the rate of three seedlings $hill^{-1}$ by maintaining a spacing of 15cm × 20 cm. The land was fertilized as per treatment specification. Necessary intercultural operations like-weeding, irrigation and drainage and pest control were done as and when necessary.

Data on growth parameters viz. plant height, panicle length, number of total tillers $hill^{-1}$, number of grains $panicle^{-1}$ and crop growth rate were collected at 15 days interval beginning at 15 DAT to 75 DAT from five randomly selected hills of each plot.

Paddy of all plots were harvested when 90% of the grain became fully golden yellow in colour. Binadhan-7 was harvested on 03 November 2016. At harvest, data were collected on plant height, panicle length, number of total tillers hill^{-1}, number of grains panicle^{-1}, 1000 grain weight (gm), grain yield, straw yield, biological yield and harvest index. The collected data were analyzed using the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using a computer package program namely, SPSS.

The results revealed that the yield components (plant height, panicle length, effective tillers hill^{-1} and grains panicle^{-1}) of Binadhan-7 responded significantly due to application of PU, USG, foliar urea and broadcast urea. Significantly the highest plant height 82.07cm was found in T2 (Urea Super Granules @ 81.5 kg/ha) which is 2.73% higher than the plant height obtained from T_1 (T_1=194 kg/ha urea at two equal splits). The lowest plant height (79.02 cm) was observed in T_3 (2% foliar spray solution @ 45 kg/ha). The highest number of panicles per hill was observed in T_2 (USG @ 81.5 kg/ha) which was 19.6% higher than the treatment $T_{1.}$ The longest panicle length (24.22 cm) was found in T_2 which was identical with T_3 and the lowest panicle length (21.61 cm) was observed in T_1.

The number grains panicle^{-1} varied from 121.33 to 149.33 with the highest value in T_2. Thousand grain weight was also highest (24.42) with the treatment T_2 which was statistically similar with T_4 (Prilled urea 138kg/ha).

The overall results indicate that the highest grain yield (3.42 t ha^{-1}) of Binadhan-7 was found in the treatment T_2 (Urea Super Granules @ 81.5 kg/ha) which was statistically similar to the treatments T_1 and $T_{4.}$ The lowest grain yield (2.68 t ha^{-1}) was found in the treatment T_3

which was statistically different from other treatments. The treatment T_2 and T_4 produced 14.38% and 6.35% higher grain yield than traditional method T_1 (194 kg/ ha urea at two equal splits). In this study the highest straw yield (9.26 t ha^{-1}) was obtained from T_2 (Urea Super Granules @ 81.5 kg ha^{-1}) which was statistically different from straw yield from other treatments of T_1, T_3 and $T_{4.}$

From the cost production ratio (CPR) the highest cost of urea application was found for treatment $T_1$and also the cost production ratio (CPR) was lowest for that treatment.

Form this study it was found that Urea Super Granules @ 81.5 kg/ha may be used to obtain the best performance on growth and yield of transplant Aman rice cv. Binadhan-7. Therefore, the treatment T_2 (USG @ 81.5 kg/ha) can be recommended is the best management practice for obtaining higher yield in transplant Aman rice.

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APPENDICES

Appendix-1

Morphological, Physical and chemical characteristics of the soils of Soil Science of the research field of HSTU

Location	HSTU research field
Agro-Ecological Zone (AEZ)	Old Himalayan Piedmont Plain
General soil type	Non Calcareous Brown Floodplain Soil
Topography	Medium high
Textural class	Sandy loam
Drainage	Well drained

Physical characteristics of soil

Sand %	60
Silt %	29
Clay %	13
Textural class	Sandy loam

Chemical characteristics of soil

pH	4.72
Organic matter (%)	1.64
Total N (%)	0.08
Available P (ppm)	55.96
Exchangeable K (me q 100 g^{-1} soil)	0.21

Available S (ppm)	19.75

(Source: Soil Resource Development Institute, Nosipur, Dinajpur)

Appendix II

ANOVA Table for Plant Height, Number of Panicle per Hill, Panicle Length, Number of Grain per Panicle and 1000 Grain Weight

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Plant height	Between Groups	16.251	3	5.417	10.668	.004
	Within Groups	4.062	8	.508		
	Total	20.313	11			
No. of panicle hill^{-1}	Between Groups	36.956	3	12.319	1.574	.270
	Within Groups	62.593	8	7.824		
	Total	99.549	11			
Panicle length	Between Groups	16.507	3	5.502	17.872	.001
	Within Groups	2.463	8	.308		
	Total	18.970	11			
No. of grain panicle-1	Between Groups	1591.557	3	530.519	160.11	.000
	Within Groups	26.507	8	3.313		
	Total	1618.063	11			

100 grain weight	Between Groups	6.483	3	2.161	71.497	.000
	Within Groups	.242	8	.030		
	Total	6.725	11			

Appendix III

ANOVA Table for Grain and Straw Yield

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Grain yield	Between Groups	.886	3	.295	3.831	.057
	Within Groups	.617	8	.077		
	Total	1.502	11			
Straw yield	Between Groups	4.518	3	1.506	16.728	.001
	Within Groups	.720	8	.090		
	Total	5.238	11			