EFFECTS OF UREA TOPDRESSING AND BALL PLACEMENT ON THE GROWTH, YIELD AND NUTRIENT CONTENT OF RE-TRANSPLANTED AMAN RICE (BINA Sail)

By

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CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF UREA TOPDRESSING AND BALL PLACEMENT ON THE GROWTH, YIELD AND NUTRIENT CONTENT OF RE-TRANSPLANTED AMAN RICE (BINA Sail)" submitted to the DEPARTMENT OF AGRICULTURAL CHEMISTRY, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of *bonafide* research work carried out by KHONDOKER MD. RUHUL AMIN, Registration. No. 10-04210, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation has duly been acknowledged.

Dated: 07.8.2012
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Dedicated to
My
Beloved Parents

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ABSTRACT

An experiment was conducted at Barga village under Kalihati upazilla of Tangail district during the period from August to December, 2011 to study the effect of urea top-dress and ball placement on the growth, yield and nutrient content of re-transplanted Aman rice (BINA sail) using completely randomized design with three replications. During the experiment, two urea application methods (U_1 = Urea top-dress and U_2 = Urea ball placement) and 4 transplanting and re-transplanting dates (T_1 = 16 September, T_2 = 23 September, T_3 = 30 September and T_4 = 07 October) were used. The highest number of total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, spikelet panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000-grain weight and the longest panicle was found in U_2 while plant height was highest in U_1. The highest N content in straw (0.40 %) and grain (1.02 %) were observed in U_2 but P & K content (in both straw and grain) were highest in U_1. In case of planting dates, T_2 showed highest results for most of the growth and yield parameters while T_4 produced the lowest. But non-effective tillers hill^{-1} and unfilled grains panicle^{-1} were highest in T_4 and lowest in T_2 and T_1. For N, P and K contents in straw and grain, the highest results were recorded in T_1 followed by T_2 while T_4 produced the lowest. Due to the interaction effects of two factors, U_2T_2 showed better results followed by U_1T_2 and U_1T_1 and poorest performances were given by U_1T_4 and U_2T_4.

CONTENTS

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LIST OF FIGURES

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LIST OF ABBREVIATIONS

%	=	Percent
@	=	At the rate
°C	=	Degree Celcius
AEZ	=	Agro Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
cv.	=	Cultivar (s)
DMRT	=	Duncan's Multiple Range Test
et al.	=	And Others
FAO	=	Food and Agriculture Organization
g	=	Gram
IRRI	=	International Rice Research Institute
LSD	=	Least Significant Difference
SAU	=	Sher-e-Bangla Agricultural University
t/ha	=	Tonne per Hectare
RCBD	=	Randomized Complete Block Design
DAT	=	Days After Transplanting

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in Bangladesh and it is also our staple food. Approximately 75% of the total cultivated land covering about 11.58 million hectares (ha) produces approximate 30 million tons of rice annually BBS (2008). The second largest part of the total production of rice comes of Aman rice after Boro. Bangladesh earns about 31.6% of her gross domestic product (GDP) from agriculture (BBS, 2008) in which rice is the main crop. Agriculture in Bangladesh is characterized by intensive crop production with rice based cropping systems. Rice is also the principal commodity of trade in our internal agricultural business. The average yield of rice in our country is around 2.45 t ha^{-1} which is less than the world average (3.1 t ha^{-1}) and frustratingly below the highest yield recorded (9.65 t ha^{-1}) in Australia (FAO, 2008).

Horizontal expansion of rice area in Bangladesh is not possible due to limited land resources, as land availability for crop production has been declining day by day because of population pressure and rapid urbanization. So, the only avenue left is to increase the production of rice through increasing crop intensity. Although the soil and climate of Bangladesh are favorable for rice cultivation throughout the year but per hectare yield of this crop is much below the potential yield level. The reasons are manifolds, some are varietals, some are technological and some are ecological. Modern high yielding varieties require higher price of seeds, fertilizers, irrigation and pesticides. Farmers of the country are poor, so they can not always afford their costs. Hence, special attention should be given for increasing the yield per unit area by applying improved management practices. On the contrary every year thousands of hectares of lands are bared and remain uncultivated due to different reasons, we can increase our rice production by utilizing these lands. But flash flood in Aman season is one of the main reasons for remaining rice fields uncultivated. These lands become water free in the late season of the Aman. In this aspect late variety of Aman rice and re-transplanting of rice seedling can help the farmers of Bangladesh.

In Bangladesh, when the photosensitive Aman rice varieties are transplanted in the late season during September-October, their sensitivity to flower in the months of October-December mostly depends on the planting dates. The phenological events of photosensitive varieties depend on the particular air temperature. BRRI (1989) and Yoshida (1981) reported that rice plants require a particular temperature for its phenological affairs such as panicle initiation, flowering, panicle exertion from flag leaf sheath and maturity and these are much influenced by the planting dates during transplanting (T) Aman season. Deviation from the optimum planting time may cause incomplete and irregular panicle exertion, increased spikelet sterility (Mangor, 1984). The optimum planting time of T. Aman rice is in August. But sometimes transplanting is delayed due to various causes such as rainfall, flood and socioeconomic factors. This late planting exposes the reproductive phases as well as phonological events of crop in an unfavourable temperature regime thereby causing high spikelet sterility and poor growth of the plant (BRRI, 1989). Halappa *et al.* (1974) reported that the performance of rice is greatly influenced by the date of transplanting due to the effect of cold hazard and incidence of biotic stress. Faria and Folegatt (1962) reported that grain yield was high for sowing in October (5.4 to 6.0 t ha^{-1}) and lower for sowing in December (1.6 to 4.8 t ha^{-1}) due to the low temperature at grain formation stages, mostly for the late cultivar. However, information regarding the effect of late planting in Aman rice is not adequate and re-transplanting is a newer idea in which rice seedling is uprooted from the seedbed and transplanted in another flood free land with 3-4 cm soil and under the soil layer a polyethylene sheet is provided for arrestation of root growth towards lower soil.

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 (IFC, 1982). Optimum dose of nitrogen fertilization plays a vital role in growth and development of rice plant. Nitrogen plays a key role in rice production and it is required in large amount. It 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). Urea can be applied in different ways. In Bangladesh, prilled urea is applied mostly as topdressing which sometimes induces imbalance in yield components consequently decreases yield. It was observed that urea super granules (USG) can minimize the loss of N from soil and hence the effectivity of N utilization increased up to 20-25% (BRRI, 2008). Deep placement of N fertilizers into the anaerobic soil zone is an effective method to reduce volatilization loss (Mikkelsen *et al.*, 1978). Field experimental results using the ^{15}N as tracer at IRRI demonstrated that N use efficiency was higher when fertilizer was placed at 10-cm soil depth (De Datta, 1981). Urea can be placed deep into the reduced soil layer at 8–10 cm soil depth by an instrument called "pneumatic urea injector" developed in the Netherlands. Field experimental results conducted at Bangladesh Rice Research Institute (BRRI) showed the superiority of this method of urea application over the conventional split broadcast method (Choudhury and Bhuiyan, 1994). In this study, apparent recovery of applied N increased considerably due to deep placement of urea. This method of N application was found effective in reducing ammonia volatilization loss resulting in increase in grain yield and fertilizer N recovery of the ^{15}N labeled urea in several field experiments (Schnier, 1995; Schnier *et al.*, 1990).

Keeping these views in mind, the present study was designed and conducted with the following objectives:

a. to study the effect of urea fertilizer placement on the growth and yield performance at different re-transplanted late Aman rice and

b. to observe the N, P and K contents of rice grain and straw as affected by the urea fertilizer placement at different re-transplanted Aman rice.

CHAPTER 2

REVIEW OF LITERATURE

Growth and development of rice plants are greatly influenced by the environmental factors i.e. air, day length or photoperiod, temperature etc., variety used and agronomic practices like transplanting time, spacing, number of seedlings, depth of planting, fertilizer management etc. Among the factors, which are responsible for the yield of rice, late transplanting of Aman rice is one of them. Nitrogen fertilizer has a great influence on the growth, yield and yield components of rice. Different forms of nitrogen fertilizers play an important role in wetland rice cultivation. Research works related to late transplanting and forms of urea application on the growth, yield and yield components of Aman rice have been reviewed in this chapter.

BRRI (1989) and Yoshida (1981) reported that rice plants require a particular temperature for its phenological affairs such as panicle initiation, flowering, panicle exertion from flag leaf sheath and maturity and these are much influenced by the planting dates during T. Aman season.

BRRI (1989) further reported that the optimum planting time of T. Aman rice is in August. But sometimes transplanting is delayed due to various physical and socioeconomic factors. This late planting exposes the reproductive phases as well as phonological events of crop in an unfavourable temperature regime thereby causing high spikelet sterility and poor growth of the plant.

Department of Agricultural Extension (DAE) conducted 432 demonstrations of the effect of USG on boro rice in 72 thanas of 31 districts during the 1990-97 winter season. It was reported that USG plots, on an average, produced higher yields than the PU plots while applying 30 to 40% less urea in the form of USG (Islam and Black, 1998).

Faria and Folegatt (1962) reported that grain yield was high for sowing in October (5.4 to 6.0 t ha^{-1}) and lower for sowing in December (1.6 to 4.8 t ha^{-1}) due to the low temperature at seed filling stages, mostly for the late cultivar.

Nahar *et al.* (2009) in a field experiment during the Aman (monsoon) season of 2008 studied the effect of low temperature stress influenced by date of transplanting on yield attributes and yields of two rice varieties. The experiment consisted of two varieties (BRRI dhan 46 and BRRI dhan 31) and 4 transplanting dates (01, 10, 20 and 30 September, 2008). BRRI dhan46 had significantly higher values of yield attributes (effective tillers $hill^{-1}$, panicles $hill^{-1}$, panicle length, spikelets $panicle^{-1}$, filled grains $panicle^{-1}$ and 1000-grain weight) and yields than the BRRI dhan 31 in late transplanted conditions. There were significant reductions in yield attributes and yields after delayed transplanting. Spikelet sterility was increased by late transplanting due to low temperature at panicle emergence stage. Yield reduction of BRRI dhan46 due to late transplanting at 10 September, 20 September and 30 September were 4.44, 8.88 and 15.55%, respectively compared to 01 September transplanting. In case of BRRI dhan 31 the reduction was more significant which were 6.12, 20.48 and 36.73%, respectively.

Vijaya and Subbaiah (1997) conducted an experiment with rice cv. IET 1444 treated with fertilizer @ 90 kg N ha^{-1} as prilled urea, large granular urea or urea super granules (USG) and 70 kg P_2O_5 ha^{-1} as single superphosphate or large diammonium phosphate, both applied by broadcasting or placement methods. They showed that plant height, number of tillers, root length, number and weight of panicles, N and P uptake, dry matter and grain yield of rice increased with increasing urea super granule size and were greater with the deep placement of both N and P compared to their broadcasting application.

Pal *et al.* (2002) conducted an experiment to find out the effect of method of planting (row and haphazard) and five hill arrangements [1 (25x12 cm^2), 2 (25x6 cm^2), 3 (25x4 cm^2), 4 (25x3 cm^2) and 5 (25x2.4 cm^2)] on the yield of late transplanted Aman rice (cv. BR23) grown under different planting dates (1^{st}, 15^{th} and 30^{th} Sept.). Yield components namely number of effective tillers m^{-2}, number of grains and that of total spikelets $panicle^{-1}$, weight of 1000 grains were notably decreased with the delay in transplanting which in turn resulted in the decreased grain yield. The grain yield gradually decreased from 1^{st} September transplanting onwards and became the lowest when the crop was transplanted on 30^{th} September.

Panday and Tiwari (1996) observed that grain yield was the highest with N applied as a basal dose of USG or mussoorie rock phosphate urea, (MRPU) applied in two split applications.

Biswas *et al.* (2001) in their experiments in Bangkok clay soil tried to investigate the influence of planting date, tiller separation and plant density on the yield and yield attributes of parent and clone plants of two transplanted rice varieties. The 15 July transplanting of mother crop and collected vegetative tillers and retransplanting on 15 August showed significantly high grain yield (3·8 t/ha). The photoperiod-insensitive variety RD23 gave higher yield (3·8 t/ha) than the photoperiod-sensitive variety KDML105 (3·0 t/ha). Tiller separation upto 4 tillers/hill did not adversely affect the mother crop. Vegetative tillers transplanted with 2–4 tillers/hill gave a similar yield as the mother crop in both the seasons. Vegetative tillers gave a higher yield than nursery seedlings transplanted on the same date. The yield components, *i.e.* weight of 1000 grains, grains/panicle and percent filled grains, showed better responses with early transplanting of KDML105 in the mother crop and vegetative tillers except for panicle number and panicle length of vegetative tillers with RD23. The results suggest that in some flood-prone lowlands, where the transplanted crop is damaged by natural hazards, vegetative propagation using tillers separated (maximum 4/hill) from the previously established transplanted crop is beneficial for higher productivity.

Subbaiah *et al.* (1994) reported that the highest grain yield (6.12 t ha^{-1}) was obtained with USG + DAP, 4.76 with PU + SSP and the lowest 2.89 t ha^{-1} with the control. Grain yield, N use efficiency and apparent N recovery are consistently higher particularly during the boro season when N as USG is deep placed. The efficiency is further improved if hole is properly closed immediately after deep J y point placement of USG.

Miah (1993) reported that plant height differed significantly among BR3, BR11, BR22, Nizershail, Pajam, and Badshabhog varieties in Aman season (Jul-Dec). Tiller number varied widely among the varieties and the number of tillers/plant at the maximum tiller number stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996.

Rahman *et al.* (2007) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during T. Aman season, 2002 to study the effect of different level of nitrogen on growth and yield of transplant Aman rice. The experiment included four treatments viz. 0, 60, 80 and 100 kg N/ha. Nitrogen level significantly influenced growth and yield components. The highest number of effective tillers/hill (9.20), maximum grains/panicle (100.80) and the highest grain yield (5.34 t/ha) were obtained with 80 kg N/ha. The highest straw yield (6.98 t/ha) was obtained at the highest nitrogen level (100 kg N/ha). The highest harvest index (44.50%) was observed at 80 kg N/ha. Results showed that 80 kg N/ha was optimum to produce maximum yield of transplant Aman rice cv. BRRI dhan32.

Quayum and Prasad (1994) showed that application of N up to 112.5 kg ha^{-1} increased grain (4.37 t ha^{-1}) and straw (5.49 t ha^{-1}) yields with fertile grain $panicle^{-1}$ being the highest at this N rate. N applied as USG gave the best yield and yield attributes. It is reported that the slow release fertilizers were effective for rainfed lowland rice.

Ahmed *et al.* (2005) were conducted a field experiment that carried out during Aman season, 2003 at the experimental field of Agrotechnology Discipline, Khulna University, Khulna to study the effect of nitrogen on different characteristics of transplanted local Aman rice variety, Jatai . The levels of nitrogen used in this study were 0, 20, 40, 60 and 80 kg/ha. Results of this study reveled that different agronomic characteristics varied significantly among the treatments. Higher N dose produced higher plant height. The highest effective tiller/hill, panicle length, filled grains/panicle, 1000-grain weight and grain yield were obtained with 40 kg N/ha. The highest and the lowest biological yield was produced with 40 kg N/ha and 0-kg N/ha respectively.

Pal *et al.* (2008) were carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during July to December 2006 to study the root growth of four Transplant Aman rice varieties as influenced by NPKS fertilization. The experiment was laid out in a split-plot design with three replications. The experiment consisted of four varieties viz. BRRI dhan 30, BRRI dhan 3l, BRRI dhan 40 and BRRI dhan 4l; and four levels of fertilizers viz. 0, 50%, 100% and 150% of the recommended dose of NPKS. BRRI dhan 4l had better performance in all root parameters. All root parameters except number of roots/hill performed better at high level of fertilizer. The interaction effect between variety and fertilizer level was significant in respect of number of roots/hill, fresh weight of root (except at 30 days after transplanting (DAT) and 90 DAT), dry weight of root, fresh weight of above ground plant part (except at 30

DAT and 90 DAT) and dry weight of above ground plant part (except at 90 DAT).

Islam *et al.* (2008) conducted a field experiment to find out the effect of nitrogen levels and transplanting dates on the yield and yield components of aromatic rice cv. Kalizira. The experiment was laid out in a randomized complete block design with three replications using four (0, 50, 100, and 150 kg N/ha) levels of nitrogen and three transplanting dates (10 August, 22 August and 04 September, 2007) along with the basal doses of triple super phosphate (TSP), muriate of potash (MOP) and gypsum. The study revealed that most of the yield and yield contributing characters with few exceptions were significantly influenced by nitrogen levels and transplanting dates. They had significant positive effect on tillers, grains/panicle and straw yield. The highest grain yield (2.63 t/ha) was observed in 100 kg N/ha with 10 August transplanting treatment and straw yield (6.43 t/ha) was found highest in 150 kg N/ha with same date of transplanting and the lowest grain (1.83 t/ha) and straw yields (5.14 t/ha) were found in N control treatment with transplanting date of 04 September. The highest grain length (4.68 mm), grain breadth (2.49 mm) and imbibition ratio (6.93) were observed with 100 kg/ha N rate coupled with 10 August transplanting, and for length-breadth ratio, the same rate recorded the highest result, but with different transplanting date i.e. 22 August.

Bahmanyar *et al.* (2010) conducted this research to investigate the effects of topdressing of different rates of nitrogen (N) and potassium (K) on grain yield and yield components of rice (*Oryza sativa cv. Tarrom*) and to observe N and K content of upper leaves analyzed at ten different times. A pot experiment was carried out on a completely randomized design with seven replications under greenhouse conditions at the Experiment Station of Sari Agricultural Sciences and Natural Resources University, Iran, during the growing season in 2008. Nitrogen was applied in the form of urea (46% N) at the rates of 0, 23 and 46 kg N/ha and potassium in the form of potassium chloride (60% K_2O) at the rates of 0, 30 and 60 kg/ha K_2O. Results indicated that panicle length, plant height, number of tiller, number of grain per panicle, hollow grain percentage, grain and biological yield were significantly affected by N and K fertilization. Maximum grain yield (75.46 g/pot) occurred at 23 kg N/ha and 30 kg/ha K_2O. At flowering stage, K content of stems were higher than leaves, and N content in flag leaves was higher than other plant parts.

Ali *et al.* (2010) conducted a experiment at multilocation testing (MLT) site, Sujanagar, Pabna during the year of 2003-2004 to find out a soil test based economically viable fertilizer recommendation for the cropping pattern Boro-T. Aman. Six treatments viz., moderate yield goal (MYG), high yield goal (HYG), integrated plant nutrient system (IPNS), recommended fertilizer (RF) of Fertilizer Recommendation Guide' 97 (BARC), farmers' practice (FP), and absolute control were employed for the study. The grain yield of Boro and T. Aman rice increased 18 and 14%, respectively, by IPNS compared to farmers' practice. Total grain yield of rice was increased by about 16% in the IPNS fertilizer package compared to farmers' practice. Fertilizer nutrients supplied both from organic and inorganic sources in adequate amount have a positive effect on productivity of soil. On an average it was found that the highest grain yields of Boro rice (5.37 t/ha) and T. Aman (4.49 t/ha) were obtained from integrated plant nutrient system (IPNS) where farmers' practice gave yield of 4.55 and 3.94 t/ha. The highest average gross margin (70385 Tk./ha) and marginal benefit cost ratio (3.78) was also obtained from IPNS plots.

Haque (1988) reported that spikelet sterility induced by low temperature at the reproductive stage of rice increased further with the increase of nitrogen supply. Spikelet sterility in Fujisaka-5 did not increase due to low temperature when nitrogen supply was increased from 10 to 40 ppm and at 80 ppm nitrogen supply it was less affected than IR36. Total nitrogen content in the leaves increased with the increase of nitrogen supply and was forced to be associated with the spikelet sterility induced by low temperature. Based on auricle distance between the last two leaves, the most sensitive stage to low temperature damage differed in Fujisaka-5 and IR36. Spikelet sterility induced by low temperature for 10 days was very high in both the varieties and the effect of nitrogen was not clear. The effect of phosphorus on the spikelet sterility induced by low temperature at reproductive stage was not clear except that at the highest phosphorus (p) level (10 ppm) the spikelet sterility increased both in Fujisaka-5 and IR 36. Spikelet sterility induced by low temperature at the reproductive stage of rice decreased with the increase of potassium (K) supply in both Fujisaka-5 and IR36. With an increase of potassium supply, nitrogen (N) content decreased in the leaves and panicles and spikelet sterility induced by low temperature decreased with an increase of the K to N ratio in the leaves and panicles. The results suggest that potassium might play a major role to counteract the low temperature damage at the reproductive stage of rice.

Oko and Onyekwere (2010) investigated the proximate chemical compositions and mineral element contents of five new lowland rice varieties viz: IR77384-12-17-3-18-2-B, IR68, PSBRc50, IR77647-3B-8-2-2-14-4 and IR75395-2B-1-1-2.4 with a view to recommending them to farmers and consumers in Ebonyi state and its environments. After the analysis, data were collected for percentage proximate composition (moisture, crude protein, fat, crude fiber, ash and carbohydrate) and mineral element contents (nitrogen, phosphorus, potassium, calcium, magnesium and sodium). The results were obtained as mean and standard deviation of the values expressed in percentage as follows; 11.50 ± 9.8 moisture 25 ± 0.8 fat, 5.8 ± 1.2 crude protein, 1.6 ± 0.3 crude fiber, 0.9 ± 0.2 ash, 78.0 ± 13.2 carbohydrate, 09± 0.04 nitrogen, 0.11±0.05 calcium, 0.21±0.002 potassium, 0.13 ± 0.00 sodium, 0.53 ± 0.03 phosphorus and 0.17 ± 0.02 magnesium. Based on the percentages of the various chemical components of these five rice varieties, we therefore persuade farmers and consumers in Ebonyi state and its environments to accept these rice varieties.

Das and Singh (1994) reported that grain yield and N use efficiency by rice were greater for deep placed USG than for USG broadcast and incorporated or three split applications of PU.

Mishra *et al.* (1994) carried out a field experiment with rice cv. Sita giving 0 or 80 kg N ha^{-1} as urea, USG and neem, lac, rock phosphate or karanj coated urea and showed that the highest grain yield was (3.39 t ha^{-1}) obtained by urea in three split applications.

From the above reviews it is cleared that urea application method and late transplanting has profound influence on the yield and yield contributing characters of Aman rice. Thus there may have enough scope investigating the effect of urea application method and transplanting date in favour of yield improvement of Aman rice cv. BINA sail.

CHAPTER 3

METHODS AND MATERIALS

The experiment was conducted at the farmer's field of the Barga village under Kalihati upazilla of Tangail district, during the period from August to December 2011. This chapter deals with a brief description of the site, soil, land preparation, intercultural operations, data recording and procedure of statistical analysis etc.

3.1 Description of experimental site

3.1.1. Location and site

The experimental field is located at the village "Barga" under Kalihati upazilla of Tangail district. The experimental area belongs to Old Brahmaputra Floodplain (Agro-Ecological Zone 9 d). The land area was situated at 24° 18′ 0″ N, latitude and 89° 55′ 12″ E longitude at an altitude of 8.6 meter above the sea level.

3.1.2 Soil

The soil of the experimental field belongs to the general soil type, gray brown terrace soil under Old Brahmaputra Floodplain. Top soils were clay loam in texture, olive gray with common fine medium.

3.1.3 Climate

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

3.2.1 Planting materials

Rice variety BINA sail was taken for this experiment. The variety is Transplant Late Aman in type. The plant grows up to 125 cm height. Seed to seed duration is 150 days. The appropriate time for seed sowing is late June to late July and transplanting should be done within August to early September. The variety is harvested from mid November to mid December and approximate yield is 5.5 t/ha (BINA, 1987).

3.2.2 Experimental treatments

The treatments included in the experiment are two factorials.

Design: RCBD with factorials

Factor 1: Urea placement method [U_1 - Urea Topdressing, U_2 - Urea Ball Placement]

Factor 2: Re-transplanting dates: 4 [T_1 : 16 September (First Transplanting in the main field and beside the main field)

T_2 : 23 September (Re-transplanting)

T_3 : 30 September (Re-transplanting)

T_4 : 07 October (Re-transplanting)]

Treatment combination = 4 x 2 = 08

Replication: 3

3.3 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each replication was divided into eight plots. The total numbers of unit plots were 24. The plot size was 2.0 m x 2.0 m. The distances between plot to plot and replication to replication were 0.5 m and 1 m, respectively. The layout of the experimental plot has been shown in Appendix 1.

3.4 Raising of seedlings

Seeds of BINA sail were collected from BINA (Bangladesh Institute of Nuclear Agriculture), Mymensingh. The seedlings were raised at the wet seed bed in SAU farm. The seeds were sprouted by soaking for 72 hours. The sprouted seeds were sown uniformly in the well-prepared seed bed in first week of August, 2011.

3.5 Land preparation

The experimental field was opened with a power tiller plough and later on, the land was ploughed and cross-ploughed three times by country plough followed by laddering to obtain the desirable tilth. The corners of the land were spaded. All kinds of weeds and stubbles were removed from the field and the land was made ready. Whole experimental land was divided into sub plots. Finally basal doses of phosphorus, potassium and sulfur fertilizers were applied in sub plots and the plots were made ready by thorough spading and leveling before transplantation.

3.6 Fertilizer application

At the time of first ploughing cow dung at the rate of 1 t ha^{-1} was applied. The plots were fertilized with 87, 60, 50 and 16 kg ha^{-1} urea, triple super phosphate

(TSP), muriate of potash (MP) and gypsum respectively (BINA, 1987). All the fertilizer except urea were incorporated with the soil one day before transplanting.

Urea application

Prilled urea was top dressed in three splits in equal ratios. The first split was applied before transplanting, the second split as topdressing at active tillering stage on 20 days after transplanting (DAT) and the third split at panicle initiation stage on 45 DAT.

Urea super granule (USG) was used for ball placement. The USG was placed in the middle of 4 hills after 7 days of transplanting and same days after re-transplanting in the main field at a time.

3.7 Transplanting of seedlings

3.7.1 Uprooting and transplanting of seedlings on the main field and polythene sheet

Six weeks old seedlings were uprooted from the seed bed carefully and transplanted at the main field according to T_1 treatment with row to row distance 22.22 cm and hill to hill distance 18.18 cm. For re-transplanting, the uprooted seedlings were placed on polythene sheet with 3-4 cm soil and at beside the plot on 16 September'11.

3.7.2 Uprooting and re-transplanting of seedlings in main plot

From the polythene based hills were uprooted again and re-transplanted in the main field as per treatments (T_2, T_3 & T_4) with row to row distance 22.22 cm and hill to hill distance 18.18 cm.

3.8 Intercultural operations

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

3.8.1 Weed control

During plant growth stage hand weedings were done according to needs.

3.8.2 Irrigation and drainage

Irrigation water was applied keeping a standing water of about 2-3 cm during the whole growing period.

3.8.3 Plant protection measure

During the growing period some plants were infested by rice stem borer (*Scirpophaga incertulus*) which was successfully controlled by applying Diazinon 60 EC @ 20 mL per 10 Liter of water for spraying. No prominent infestation of insect-pests and diseases were observed in the field.

3.9 Harvest and post harvest operation

The crop was harvested after the grains attained maturity. The grains were threshed, cleaned and sun dried to record grain yield/plot.

3.10 Sampling and data collection

Data collections from the experiment on different growth stages were done under the following heads as per experimental requirements.

3.10.1 Plant height (cm)

Heights of the pre-selected 10 hills were taken by measuring the distance from base of the plant to the tip of the flag leaf after heading. The collected data were finally averaged.

3.10.2 Number of effective and non-effective tillers hill^{-1}: Number of effective and non-effective tillers was counted from 10 preselected hills after harvesting and finally averaged.

3.10.3 Number of filled grains and unfilled grains panicle^{-1}: Number of filled grains and unfilled grains were counted from 10 panicles at each plot. Lack of any food materials inside the spikelets were denoted as unfilled grains.

3.10.4 Thousand grain weight (g): One thousand grains were randomly collected from each plot and were sun dried and weighed by an electronic balance.

3.10.5 Grain yield (t/ha): Four square meter (m^2) area (each plot) were harvested. The grains were threshed, cleaned, dried and then weighed in kg. Thereafter it was converted as ton per hectare (t/ha).

3.10.6 Determination of total Nitrogen

The macro kjeldahl method was used to determine the total nitrogen in straw and grain of plant samples. Three steps were involved in this method. These are as follows:

1. Digestion : In this step the organic nitrogen was converted to ammonium sulphate by sulphuric acid and digestion accelerators (Catalyst Mixture) at a temperature of 360-440^{0}C.

$$N + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

2. Distillation : In this step, the solution was made alkaline for the distillation of ammonia. The distillated ammonia was received in boric acid solution.

$$(NH_4)_2SO_4 + NaOH \longrightarrow Na_2SO_4 + NH_3 + H_2O$$

$$NH_3 + H_3BO_3 \longrightarrow (NH_4)_2BO_3 + H_2O$$

3. Titration : To determine the amount of NH_3, ammonium borate was titrated with standard sulfuric acid.

$$(NH_4)_2BO_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4 + H_3BO_3$$

Reagents : 4 % Boric Acid solution, Mixed Indicator (Bromocresol Green And Methyl Red), 4 % Sodium Hydroxide solution, standard Sulfuric Acid solution and 0.05 N Na_2CO_3 solution.

Procedure :

About 0.25 g of oven-dried straw/grain sample was weighed and then transferred into a 250 mL Pyrex conical flask. Then 5.0 g catalysts mixer (K_2SO_4: CuSO4.5H_2O: Se =100: 10: 1) was added into the flask. About 25 mL H_2SO_4 was also added in to the flask. The flask was heated until the solution become clear and then allowed to cool. After digestion, 40% NaOH was added in to the conical flask and attached quickly to the distillation set. Then the flask was heated continuously. In the meantime, 25mL of 4% boric acid solution and 2-4 drops of mixed indicator was taken in 5% receiver conical flask. After distillation, the distillate was collected into receiver conical flask. The distillate was titrated with standard H_2SO_4 taken from a burette until the green color completely turns to pink. The same procedure was followed for a blank sample.

The result was calculated using the following formula –

$\% N = (T\text{-}B) \times N \times 1.4/S$

T = Titration value for sample (ml.), B = Titration value for blank (mL)

N = Normality of H_2SO_4, S = Weight of the sample (g),

1.4 = Conversion factor

3.10.7 Determination of Phosphorus (P)

Principle:

By ascorbic acid blue color method the phosphorus content in rice straw and grain were determined. This method is based on the principle that in an acid molybdate solution containing orthophosphate ($H_2PO_4^-$) ions, a phosphomolybdate complex forms that can be reduced by ascorbic acid and other reducing agents to a molybdenum blue color.

$(NH_4)_6Mo_7O_{24}.4\,H_2O + H_2SO_4 = (NH_4)_2MoS_4$

$(NH_4)_2MoS_4 + H_2PO_4^- = (NH_4)_3PMo_{12}O_{40}$ [Ammonium phosphorus molybdate, oxidized, colorless]

$(NH_4)_3PMo_{12}O_{40} + C_6H_8O_6 =$ Ammonium phosphorus molybdate (Reduced, Blue color)

Reagents:

1. Mixed reagent:

Solution A:

About 12.0g ammonium molybdate $[(NH_4)_6Mo_7O_{24}.4\ H_2O]$ was dissolved in 250 mL distilled water.

Solution B:

At first 0.2908g antimony potassium tartarate $[K(SbO)C_4H_4O_6.1/2H_2O]$ was dissolved in 1000 mL of 5N H_2SO_4 (148 mL conc. H_2SO_4/Liter) the two solutions were mixed together thoroughly. Then the volume was made to 2000 mL distilled water.

2. Color developing reagent:

About 0.53g (or.1.06g or 2.65g) of ascorbic acid was added to 100 mL (or 200 mL or 500 mL) of the mixed reagent.

Preparation of plant extract:

0.25 g of dry rice straw/grain were weighed, and then transferred into 250 mL Pyrex conical flasks. Then 10 mL 2:1 nitric-perchloric acid mixture was added into each flask and allowed to stand overnight or until the vigorous reaction phase is over. After the preliminary digestion, the conical flasks were placed on a hot plate in digestion chamber and then temperature was raised to 150°C for one hour. The temperature was increased slowly up to 300^{0}C. After the digestion the conical flasks were lifted out of the digester and allowed to cool at room temperature. The solution was taken in 100 mL volumetric flask through funnel and volume with distilled water up to the mark (Jackson, 1973).

Procedure:

20 mL of the extract was pipette out in a 100 mL volumetric flask. Then 20 mL color developing reagent was added slowly and carefully to prevent loss of sample due to excessive foaming. After the evolution of CO_2; has ceased the flask was shake gently to mix the contents. Distilled water was added to make the volume up to the mark of the flask. By spectrophotometer, the color intensity (% absorbance) was measured at 660 ηm.

3.10.8 Determination of Potassium (K)

Principle:

If a solution containing metallic salt (or some other metallic compound) is aspirated in a flame; the metal ion emits radiation at a characteristic wavelength having the definite color (e.g. potassium emits brick red color when aspirated in a flame). The intensity of the radiation emitted by the element (or metal ion) is directly proportional to the concentration of that element in solution.

Procedure:

Plant sample (for both straw and grain) were prepared by digestion as for phosphorus. Then the amount of potassium was estimated from prepared sample with the help of a flame photometer at 589 ηm.

3.11 Statistical Analysis

The data were compiled and tabulated in proper form and were subjected to statistical analysis. Analysis of variance was done following the computer package MSTAT-C program developed by Russel, 1986. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test at 5% level of significance (Gomez and Gomez, 1984).

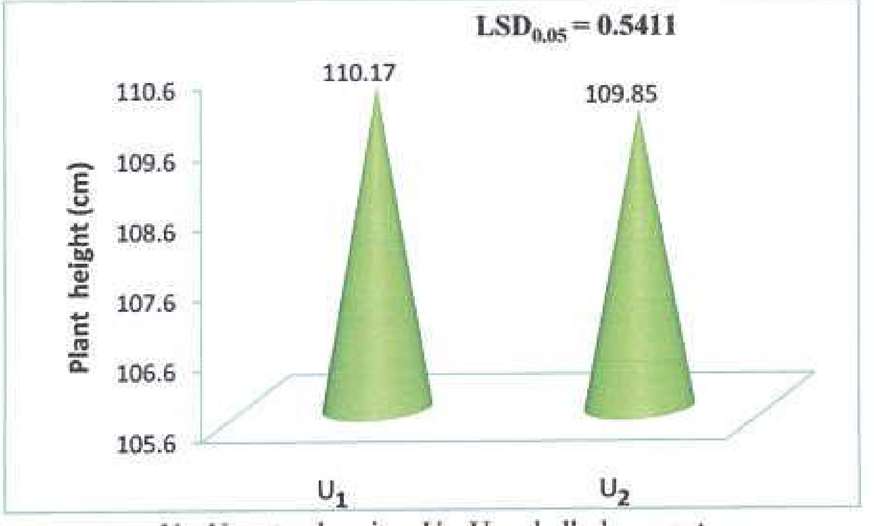
CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises of presentation and discussion of the results obtained from the study to see the effect of application method of urea on the growth, yield and nutrient content of re-transplanted Aman rice (BINA sail). Effects of different treatments on growth, yield and nutrient contents are presented hereunder-

4.1 Plant height (cm)

Plant height of BINA sail showed a significant variation due to the different application methods of urea (Figure 1 and Appendix 2). The tallest plant (110.17 cm) was obtained from urea topdressing (U_1) while urea ball placement (U_2) gave the shortest plant (109.85 cm) which is not far behind from U_1.

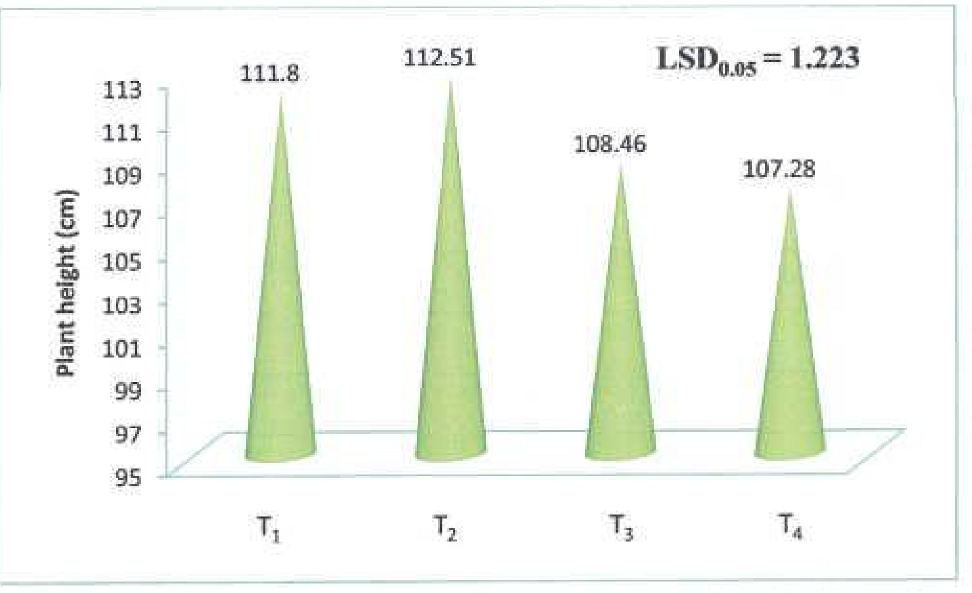


U_1- Urea topdressing, U_2- Urea ball placement

Figure 1. The effect of urea application methods on plant height (mean of four transplanting and re-transplanting dates)

It was observed from the results presented in Figure 2 that the transplanting and re-transplanting dates have significant influence on plant height. The tallest plant

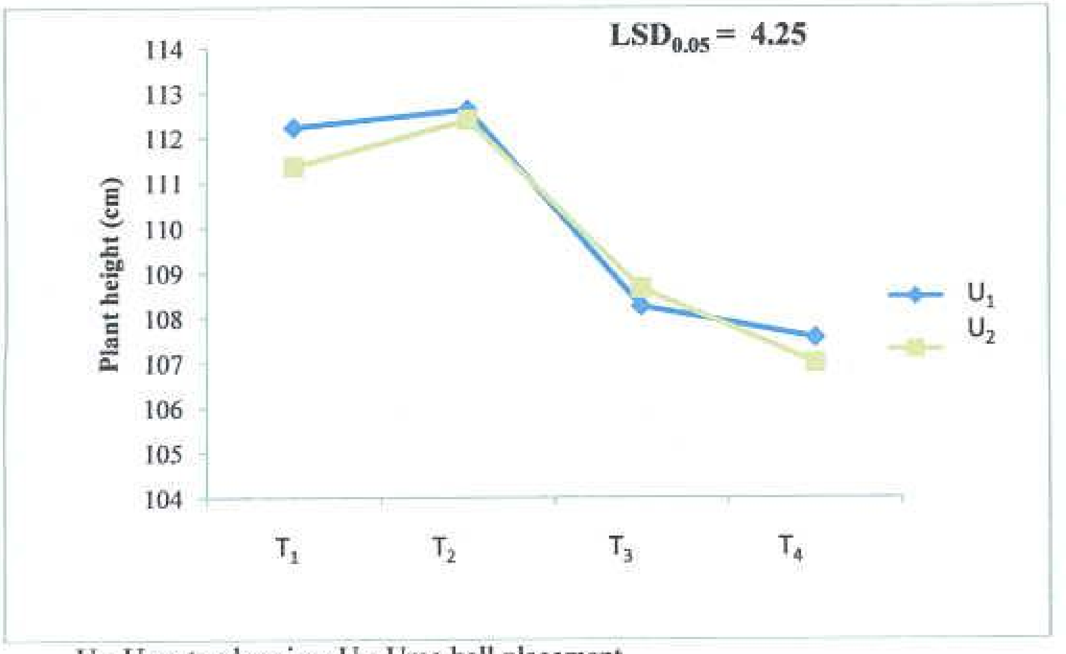
(112.51 cm) was obtained from T_2 (re-transplanted on 23 September) which was statistically similar with T_1 (transplanted on 16 September). On the other hand, re-transplanted on 07 October (T_4) produced the shortest one (107.28 cm) (Appendix 3).



T_1 : Transplanted on 16 September, T_2 : Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 2. The effect of transplanting and re-transplanting dates on plant height (mean of two urea application methods)

The results presented in Figure 3 showed that the plant height differs significantly due to the interaction effect of urea application methods and planting dates of late Aman cultivar (BINA sail). The tallest plant (112.63 cm) was obtained from U_1T_2 (topdressing of urea and re-transplanted on 23 September) which was statistically similar with U_2T_2 and U_1T_1 (Appendix 4). On the other hand, U_2T_4 (urea ball placement and re-transplanted on 07 October) produced the shortest one (107.00 cm) which was statistically similar with U_1T_4.



U_1- Urea topdressing, U_2- Urea ball placement

T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

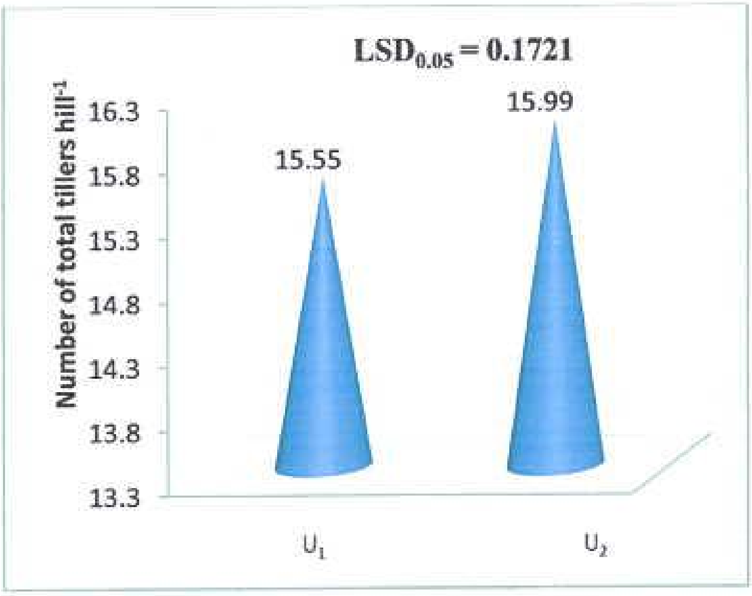
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 3. The effect of urea application methods on plant height under different transplanting and re-transplanting dates

Hasanuzzaman *et al.* (2009) observed that application of granular urea at higher rate by split method facilitated higher vegetative growth and hence maximum plant height was attained. This result was also supported by Islam *et al.* (2008). In general, plant height increased with the increasing level of nitrogen (Singh and Singh, 1984 and Alam, 2002). BRRI (1989) reported that the optimum planting time of T. Aman rice is August. But sometimes transplanting is delayed due to various physical and socioeconomic factors. This late planting exposes the vegetative and reproductive phases as well as phonological events of crop and poor growth of the plant.

4.2 Number of tillers hill^{-1}

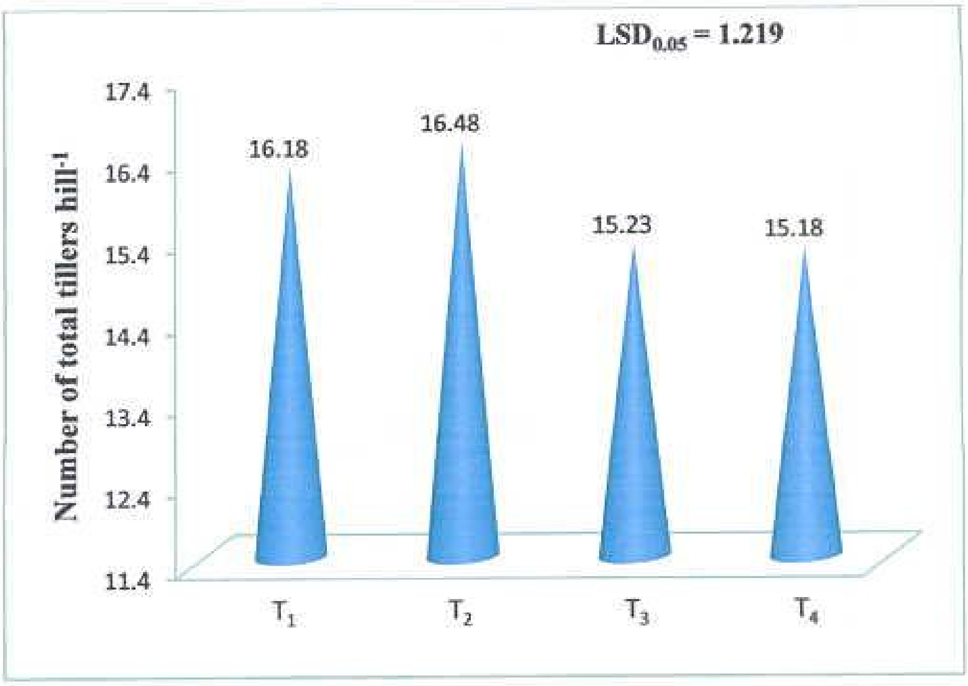
Number of tillers hill^{-1} of rice plant BINA sail was significantly affected by different urea application methods (Figure 4 and Appendix 2). The highest number of tillers hill^{-1} was found from urea ball placement (15.99) whereas topdressing of urea gave 15.55 tillers hill^{-1}. Chander and Pandey (1996) conducted an experiment where it was revealed that number of tillers hill^{-1} was the highest in case of urea application as urea super granule.



U_1- Urea topdressing, U_2- Urea ball placement

Figure 4. The effect of urea application methods on number of total tillers per hill (mean of four transplanting and re-transplanting dates)

Total tiller number hill^{-1} varied significantly due to the effect of transplanting and re-transplanting dates (Figure 5). The highest number of tillers hill^{-1} (16.48) was obtained from T_2 (re-transplanted on 23 September) while re-transplanted on 07 October (T_4) gave the lowest result (15.18) (Appendix 3).

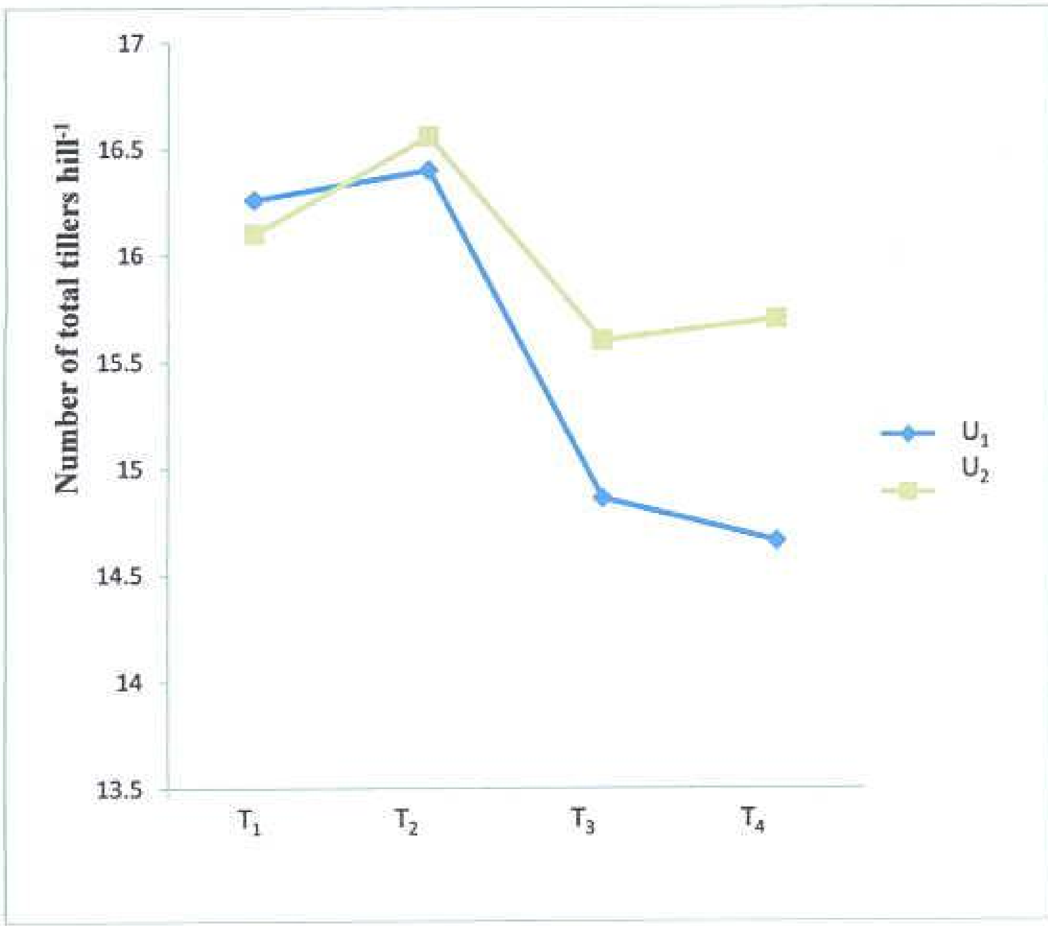


T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 5. The effect of transplanting and re-transplanting dates on number of total tillers hill^{-1} (mean of two urea application methods)

No significant variation was found in number of total tiller number hill^{-1} due to the interaction effect of urea application methods and planting dates (Figure 6 and Appendix 4). But the highest number of tiller number hill^{-1} (16.56) was found from U_2T_2 while U_1T_4 gave lowest result (14.66).

Hasanuzzaman *et al.*(2009) observed that at initial stage of growth, application of granular urea with 3 equal splits produced the highest number of tillers (7.6); but at later stages (60 and 90 DAT) maximum number of tillers was produced with the application of urea supergranules (USG) @ 75 kg ha^{-1}. Deep placement of USG showed the highest number of tillers might be due to little loss of N from soil and slowly releasing process. Mangor (1984) found that late transplanting can affect on plant growth negatively and as a result tiller number hill^{-1} was reduced.

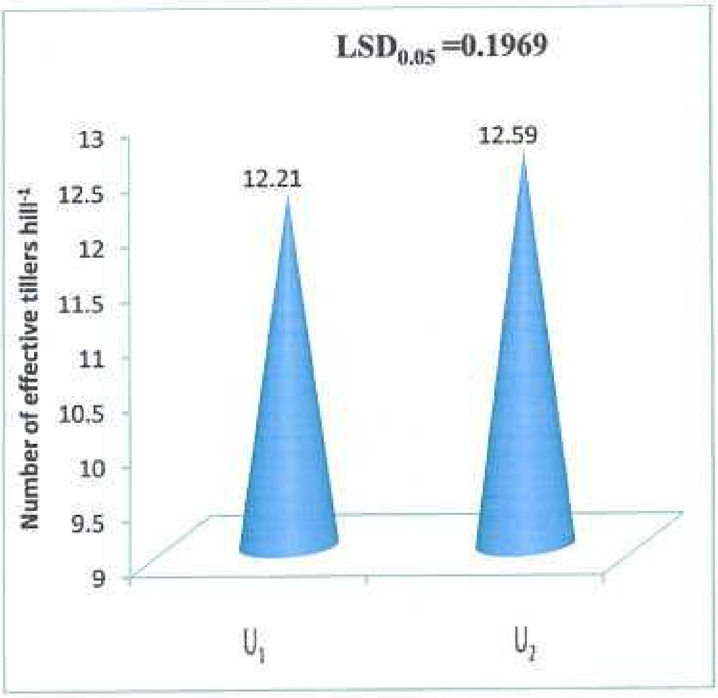


U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 6. The effect of urea application methods on total tiller number hill^{-1} under different transplanting and re-transplanting dates

4.3 Number of effective tillers hill^{-1}

The effective tiller hill^{-1} significantly differed due to the effect of urea fertilizer application methods (Figure 7).The highest number of effective tillers hill^{-1} (12.59) was found from urea ball placement (U_2) while urea topdressing (U_1) gave the lowest number of effective tillers hill^{-1} (12.21) (Appendix 2).

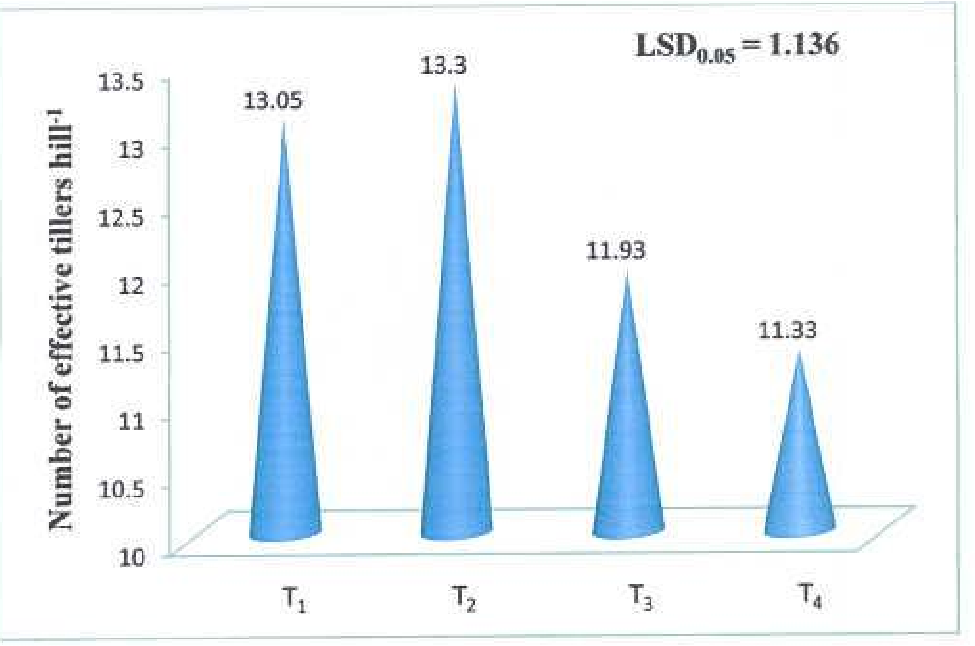


U_1- Urea topdressing, U_2- Urea ball placement

Figure 7. The effect of urea application methods on the number of effective tillers hill^{-1} (mean of four transplanting and re-transplanting dates)

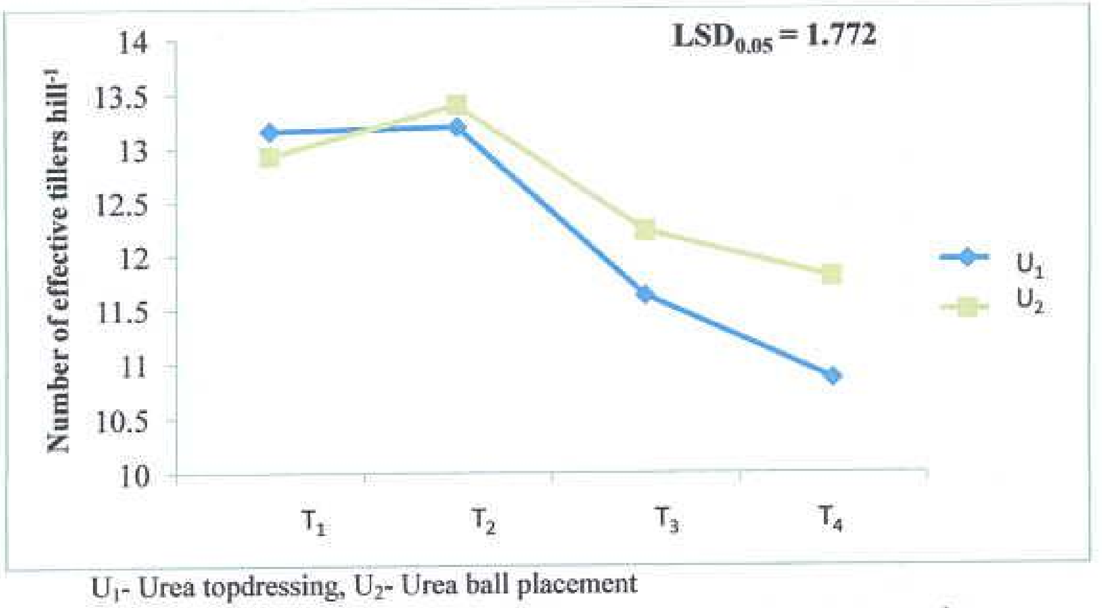
There was significant influence on number of effective tillers hill^{-1} shown by transplanting and re-transplanting dates (Figure 8). The highest number (13.30) of effective tillers hill^{-1} was obtained from T_2 (re-transplanted on 23 September) while re-transplanted on 07 October (T_4) gave the lowest number of effective tillers hill^{-1} (11.33) (Appendix 3).

Interaction of urea application methods and planting dates showed significant influence on the number of effective tillers hill^{-1} (Figure 9). The highest number of effective tillers (13.40) hill^{-1} was found from U_2T_2 which was statistically similar with U_1T_2, U_1T_1 and $U_2T_{1.}$ On the other hand, U_1T_4 gave lowest number of effective tillers per hill^{-1} (10.86) (Appendix 4).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 8. The effect of transplanting and re-transplanting dates on number of effective tillers hill^{-1} (mean of two urea application methods)



U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 9. The effect of urea application methods on number of effective tillers hill^{-1} under different transplanting and re-transplanting dates

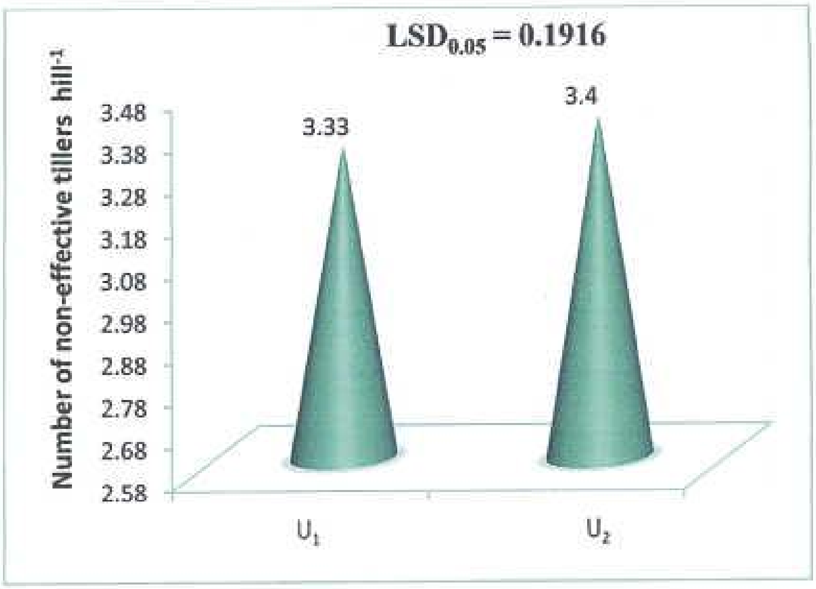
Adequate amount of nitrogen as USG probably favored the cellular activities during panicle formation and development which led to increased number of productive tiller per hill. Singh and Singh (1986) also reported the similar findings from their experiment.

Nahar *et al.* (2009) found that low temperature stress had significantly lower values of yield attributes such as effective tillers hill^{-1} in the BRRI dhan 31 in late transplanted conditions.

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

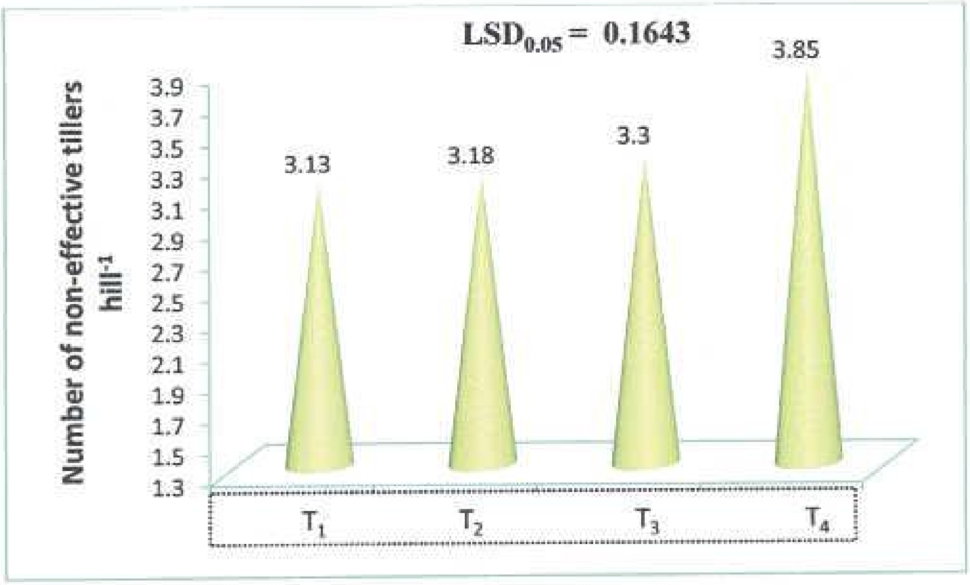
The effect of urea application methods on the number of non-effective tillers hill^{-1} was not significant. But the higher number of non-effective tillers (3.40) hill^{-1} was found from U_2 which was almost similar with U_1 (3.33) (Figure 10 and Appendix 2).

Transplanting and re-transplanting dates had significant influence on number of non-effective tillers hill^{-1} (Figure 11). The highest number of non-effective tillers hill^{-1} (3.85) was obtained from T_4 (re-transplanted on 07 October) while the lowest number of non-effective tillers hill^{-1} was obtained from T_1 (transplanted on 16 September) (Appendix 3).



U_1- Urea topdressing, U_2- Urea ball placement

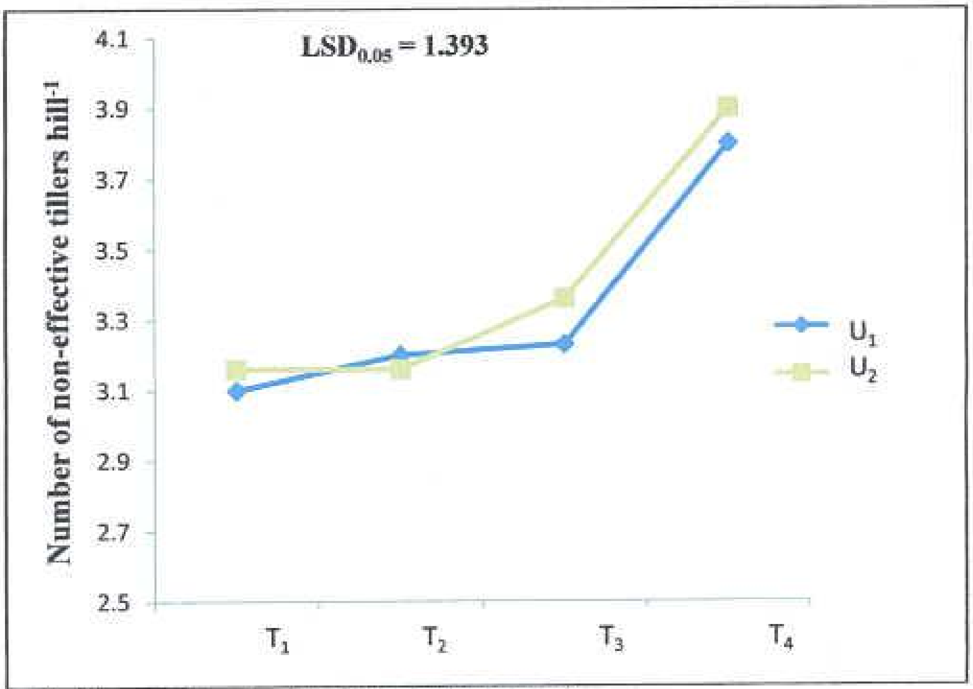
Figure 10. The effect of urea application method on number of non-effective tillers hill^{-1} (mean of four transplanting and re-transplanting dates)



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 11. The effect of transplanting and re-transplanting dates on number of non-effective tillers hill^{-1} (mean of two urea application methods)

No significant variation was found on number of non-effective tillers $hill^{-1}$ due to the interaction effect of urea application methods and planting dates (Figure 12 and Appendix 4). The highest number of non-effective tillers (3.90) $hill^{-1}$ was found from U_2T_4. On the other hand, U_1T_1 gave lowest number of effective tillers (3.10) $hill^{-1}$.



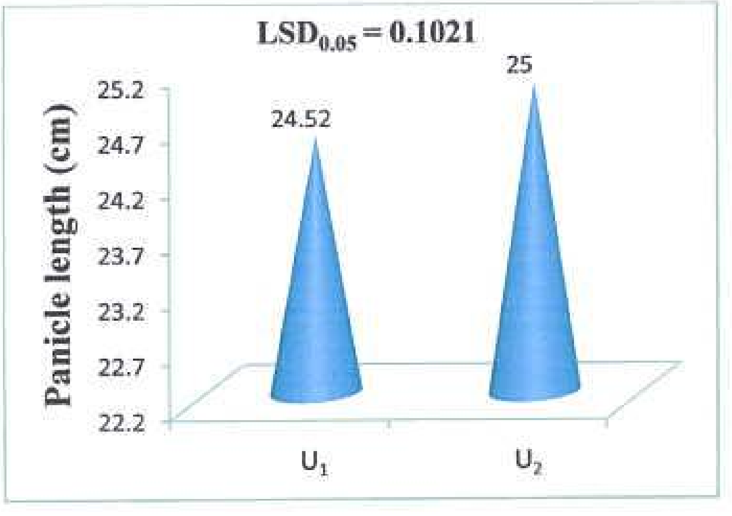
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 12. The effect of urea application methods on number of non-effective tillers $hill^{-1}$ under different transplanting and re-transplanting dates

The present study keep in with the study of Mangor (1984) who reported that deviation from the optimum planting time may cause incomplete vegetative stage and irregular panicle exertion. Therefore, the number of ineffective tiller may increase.

4.5 Panicle length

The urea topdressing and ball placement significantly influenced the panicle length of BINA sail (Figure 13). The highest length of panicle (25.00 cm) was obtained from urea ball placement (U_2), whereas urea topdressing (U_1) produced the shortest one (24.52 cm) (Appendix 2).

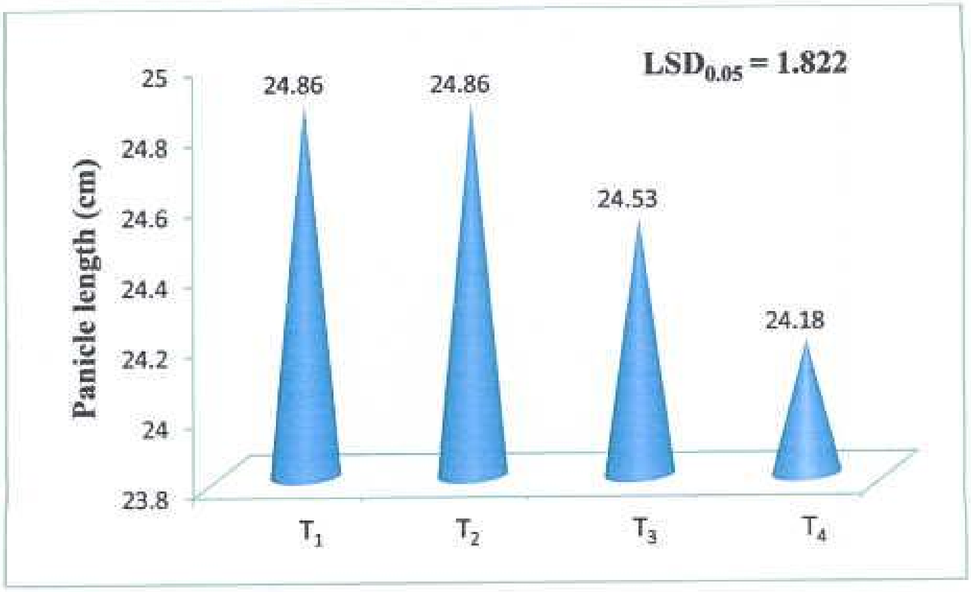


U_1- Urea topdressing, U_2- Urea ball placement

Figure 13. The effect of urea application methods on length of panicles (mean of four transplanting and re-transplanting dates)

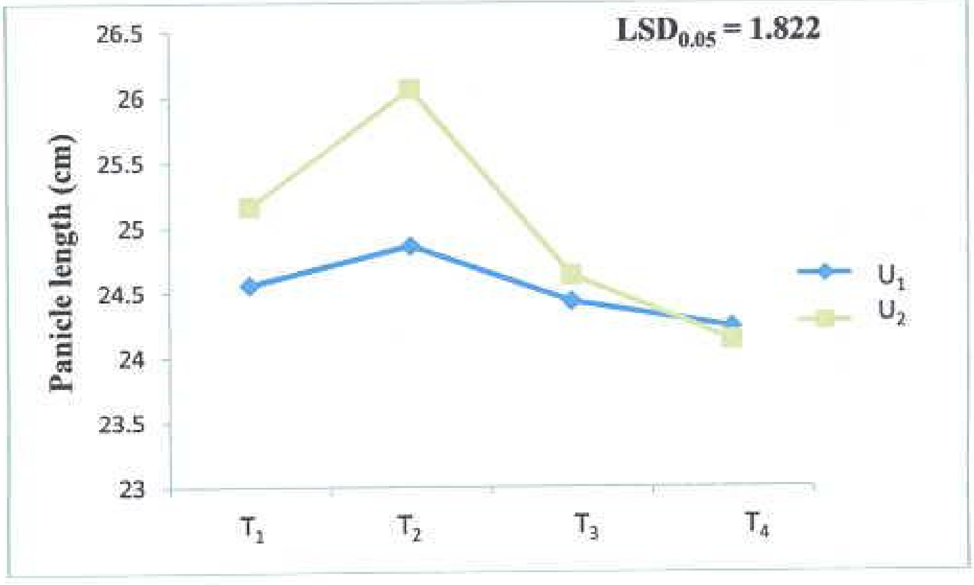
Significant influence was observed on panicle length (cm) due to the effect of transplanting and re-transplanting dates (Figure 14). The highest length of panicle (25.47 cm) was obtained from T_2 (re-transplanted on 23 September) while re-transplanted on 07 October (T_4) gave the lowest result (24.18 cm) (Appendix 3).

Panicle length didn't vary significantly due to the interaction effect of urea application methods and planting dates (Figure 15 and Appendix 4). The longest panicle (26.07 cm) was found from U_2T_2 and shortest (24.13 cm) was recorded in U_2T_4.



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 14. The effect of transplanting and re-transplanting dates on panicle length (mean of two urea application methods)



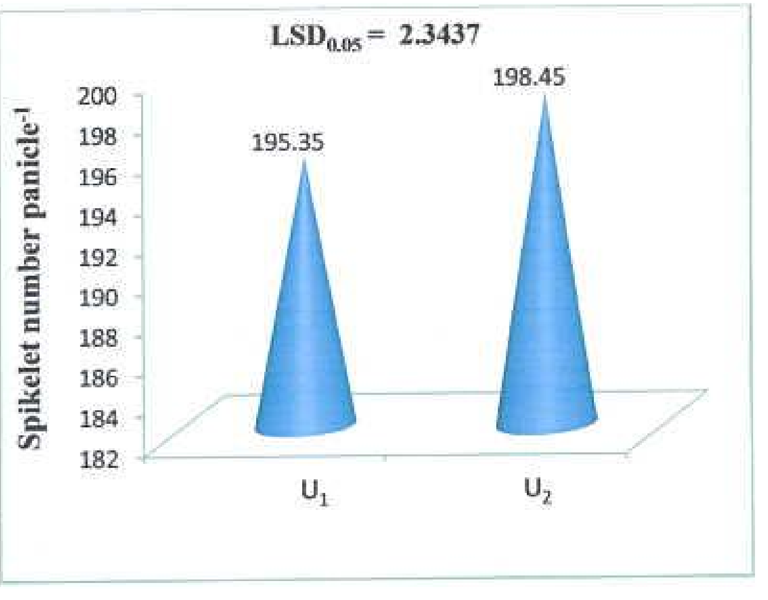
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 15. The effect of urea application methods on panicle length under different transplanting and re-transplanting dates

Rama *et al.* (1989) found that urea super granule gave better results in respect of panicle length than urea broadcasting. Hasanuzzaman *et al.* (2009) in a study found that the length of panicle in late transplanted Aman rice ranged from 23.59 cm to 21.3 cm which matched with the present study.

4.6 Number of spikelet

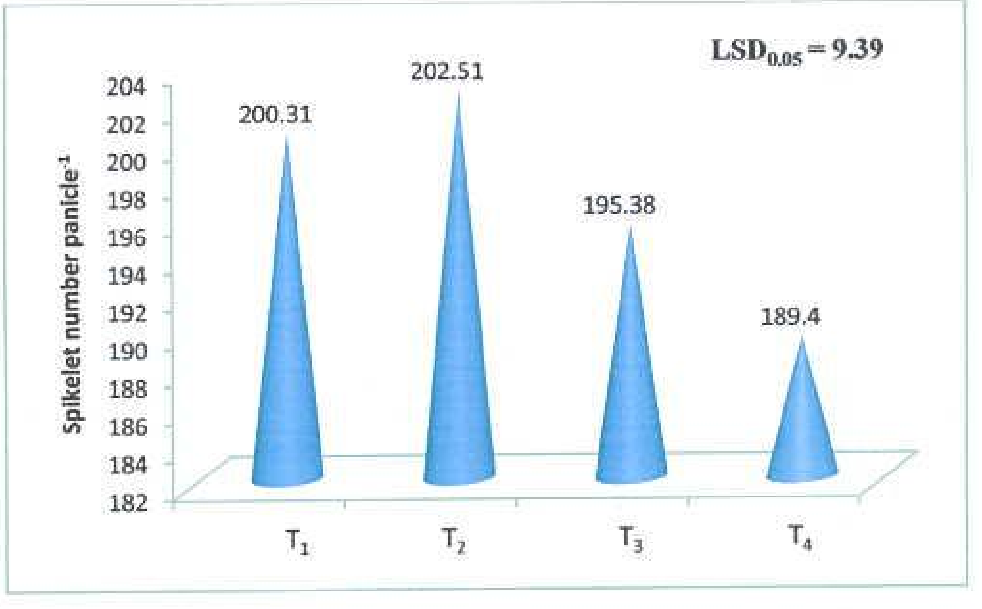
The number of spikelet panicle^{-1} of BINA sail rice was significantly affected by different urea application methods (Figure 16). The highest number of spikelet (198.45) panicle^{-1} was recorded for urea ball placement (U_2) and urea topdressing gave the lowest spikelet (195.35) panicle^{-1} (Appendix 2).



U_1- Urea topdressing, U_2- Urea ball placement

Figure 16. The effect of urea application methods on number of spikelet panicle^{-1} (mean of four transplanting and re-transplanting dates)

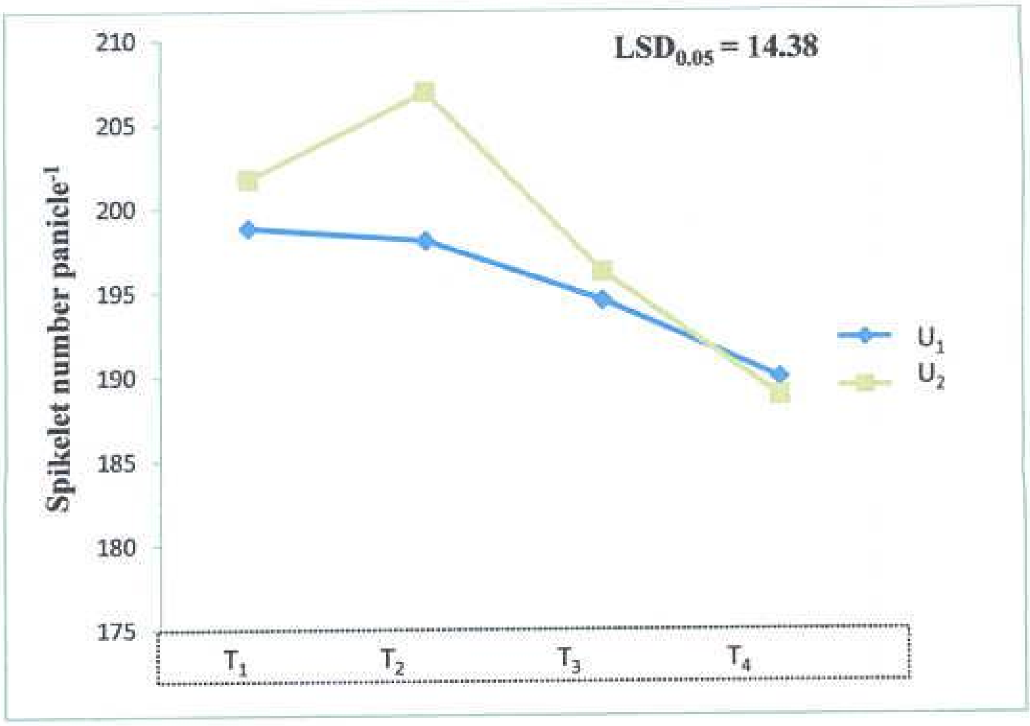
The number of spikelet panicle^{-1} differed significantly due to the different transplanting and re-transplanting dates (Figure 17). The highest number of spikelet (202.51) panicle^{-1} was obtained from T_2 (re-transplanted on 23 September) which was statistically similar with T_1 (transplanted on 16 September) and the lowest (189.40) was recorded from T_4 (re-transplanted on 07 October) (Appendix 3).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 17. The effect of transplanting and re-transplanting dates on number of spikelet panicle^{-1} (mean of two urea application methods)

It was revealed from the results presented in Figure 18 that interaction effect of urea application methods and planting dates have significant effect on number of spikelet panicle^{-1}. The highest number of spikelet panicle^{-1} (206.93) was recorded from U_2T_2 while the lowest (188.86) was recorded from U_2T_4 which was statistically similar with U_1T_4 (Appendix 4).



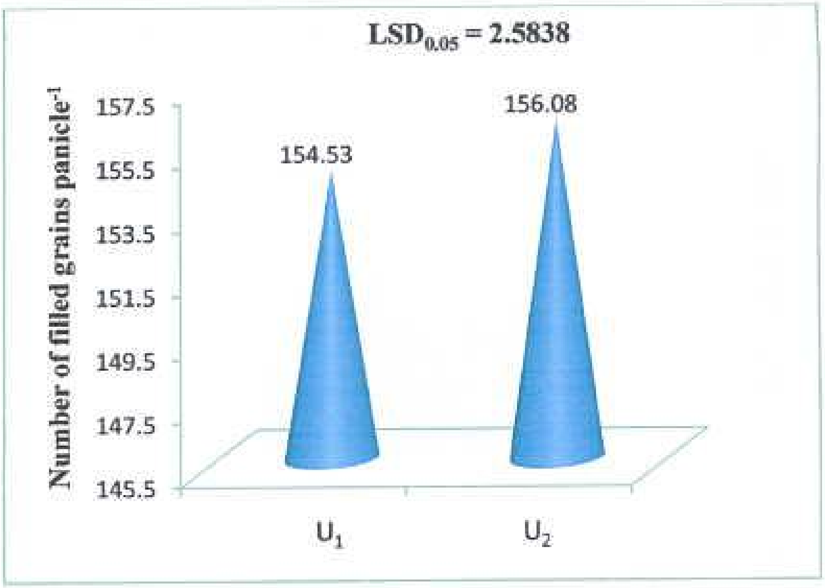
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 18. The effect of urea application methods on number of spikelet panicle^{-1} under different transplanting and re-transplanting dates

According to Hasanuzzaman *et al.* (2009), urea super granules @ 75 kg ha^{-1} gave superior number of spikelet panicle^{-1} than split application of urea prill. Pal *et al.* (2002) found that the number of spikelet panicle^{-1} gradually decreased with the late in transplanting date.

4.7 Number of filled grain

A significant variation was recorded due to the different application method of urea for number of filled grain (Figure 19) panicle^{-1}. The maximum number of filled grains (156.08) panicle^{-1} was recorded for urea ball placement (U_2) followed by topdressing of urea (154.53) (Appendix 2).

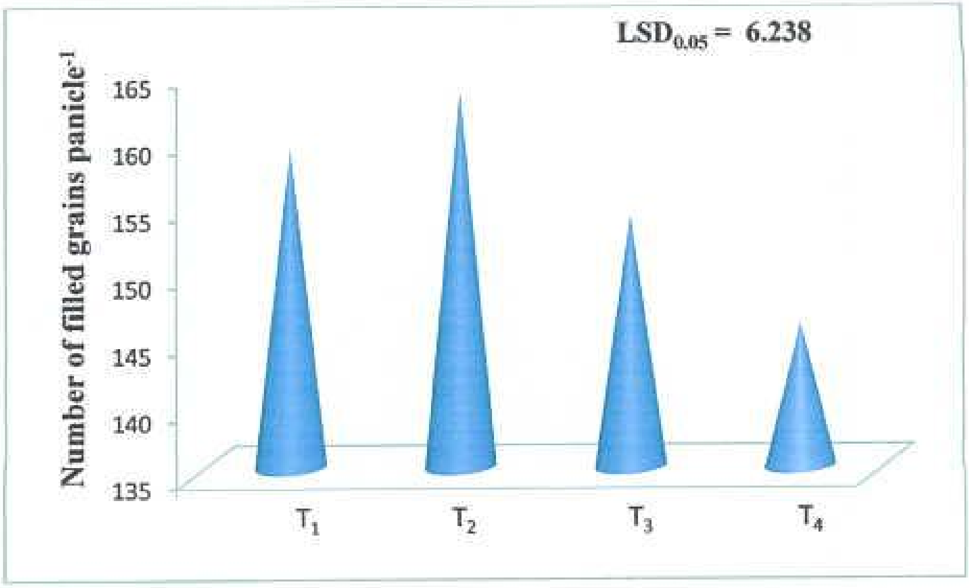


U_1- Urea topdressing, U_2- Urea ball placement

Figure 19. The effect of urea application methods on number of filled grains panicle^{-1} (mean of four transplanting and re-transplanting dates)

Significant influence was observed on number of filled grain panicle^{-1} due to the different transplanting and re-transplanting dates (Figure 20 and Appendix 3). The highest number of filled grain (163.0) panicle^{-1} was obtained from T_2 (re-transplanted on 23 September) and the lowest (145.66) was recorded from T_4 (re-transplanted on 07 October).

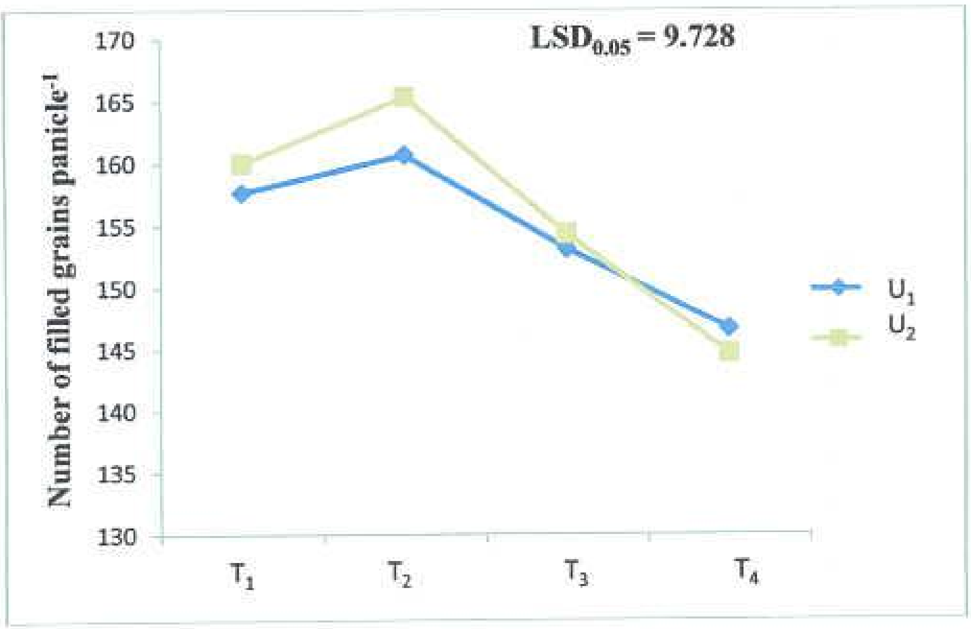
It was revealed from the results presented in Figure 21 that interaction effect of urea application methods and planting dates have significant effect on number of filled grain panicle^{-1}. The highest number of filled grain (165.3) panicle^{-1} was recorded from U_2T_2 while the lowest (144.7) was recorded from U_2T_4 which was statistically similar with U_1T_4 (Appendix 4).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 20. The effect of transplanting and re-transplanting dates on number of filled grain panicle^{-1} (mean of two urea application methods)



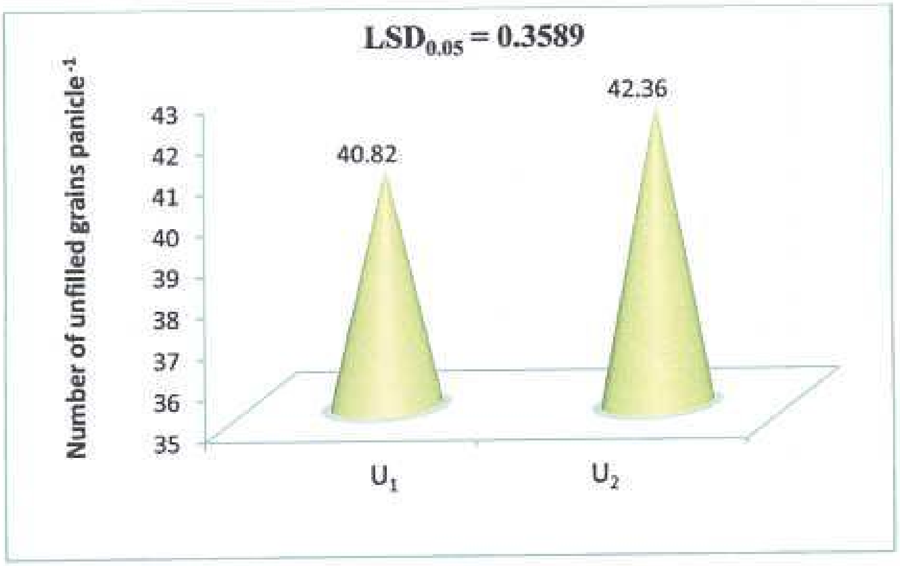
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 21. The effect of urea application methods on number of filled grain panicle^{-1} under different transplanting and re-transplanting dates

Rama *et al.* (1989) and Kapre *et al.*(1996) observed that application of urea super granule exerted considerable positive effect on the number of filled grain panicle^{-1}. Nahar *et al.* (2009) found low temperature causes various types of injuries in rice plants, but the most important one is spikelet sterility. In their experiment they found, production of filled grains decreased with the delay of transplanting which was due to occurrence of low temperature at anthesis and spikelet primordial formation.

4.8 Number of unfilled grain

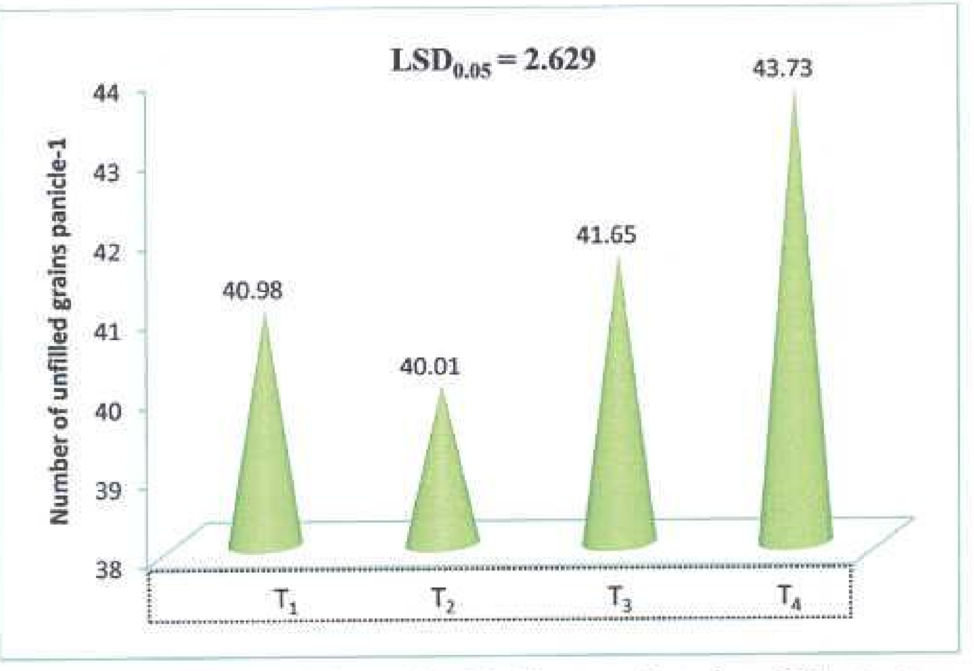
A clear difference was observed in case of number of unfilled grain panicle^{-1} among the two methods of urea application treatments (Figure 22). The maximum number of unfilled grains (42.36) panicle^{-1} was recorded for urea ball placement (U_2) followed by U_1 (40.83) (Appendix 2).



U_1- Urea topdressing, U_2- Urea ball placement

Figure 22. The effect of urea application method on unfilled grain panicle^{-1} (mean of four transplanting and re-transplanting dates)

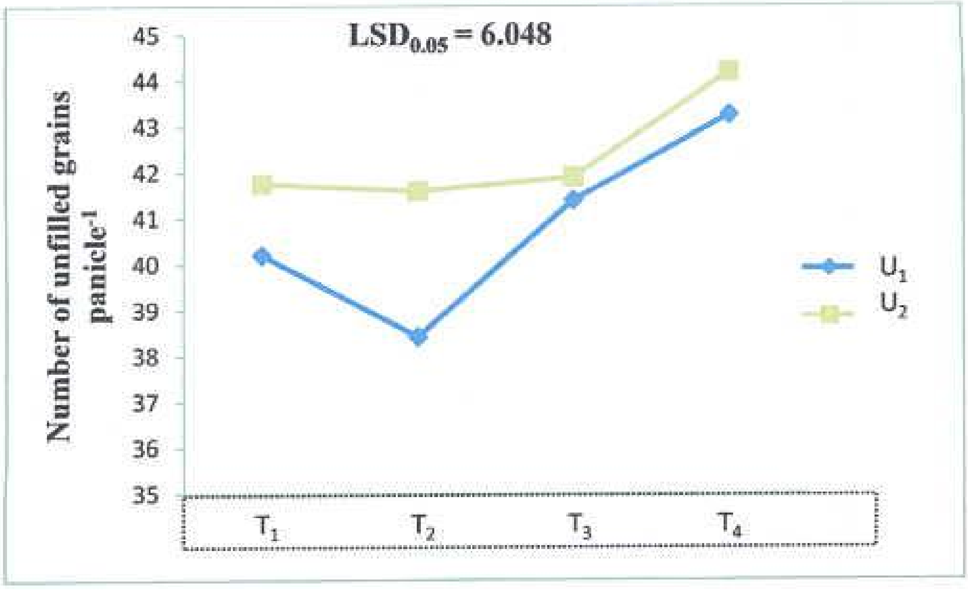
Transplanting and re-transplanting dates have significant influence on number of sterile or unfilled grain panicle^{-1} (Figure 23). From T_4 (re-transplanted on 07 October), the highest number of unfilled grain panicle^{-1} (43.73) was obtained whereas the lowest (40.01) was recorded from T_2 (re-transplanted on 23 September) which was statistically similar with T_1 (transplanted on 16 September) (Appendix 3).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 23. The effect of transplanting and re-transplanting dates on number of unfilled grain panicle^{-1} (mean of two urea application methods)

Interaction of urea application methods and planting dates showed no significant influence on number of unfilled grain panicle^{-1}. From U_2T_4 the highest number of unfilled grain panicle^{-1} (44.20) was obtained whereas the lowest (38.43) was recorded from U_1T_4 (Figure 24 and Appendix 4).



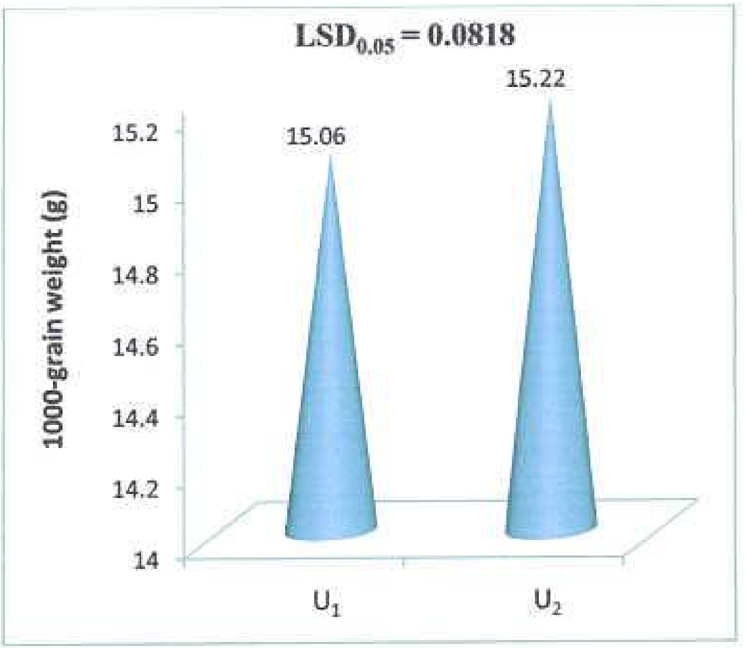
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 24. The effect of urea application methods on number of unfilled grain panicle^{-1} under different transplanting and re-transplanting dates

Rama *et al.* (1989) mentioned that Urea super granules (USG) produced significantly higher number of grains panicle^{-1} than split application of prilled urea. Shimizu and Kumo (1967) reported a wide range of abnormal spikelets, all of which were induced under the low temperature treatments at the young panicle primordial differentiation stage. As the temperature in Bangladesh is lower in December it induced in increased sterile grain.

4.9 1000-grain weight

1000-grain weight (g) was comparatively higher (15.22 g) in urea ball placement (U_2) than the topdressing of urea (15.06 g) (Figure 25 and Appendix 2). Hasanuzzaman *et al.* (2009) observed that Urea super granules gave higher 1000-grain weight than split application and foliar spray of urea.

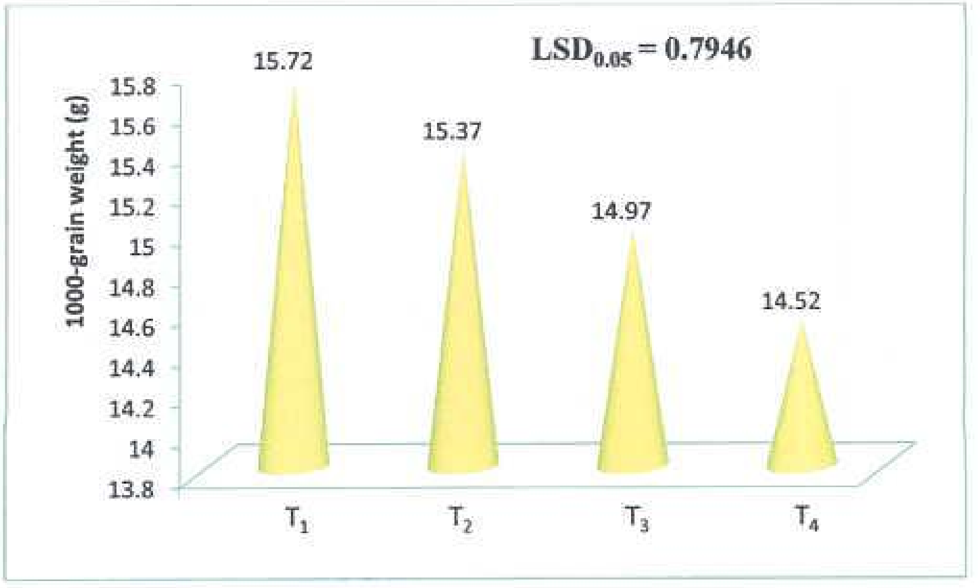


U_1- Urea topdressing, U_2- Urea ball placement

Figure 25. The effect of urea application methods on 1000-grain weight (mean of four transplanting and re-transplanting dates)

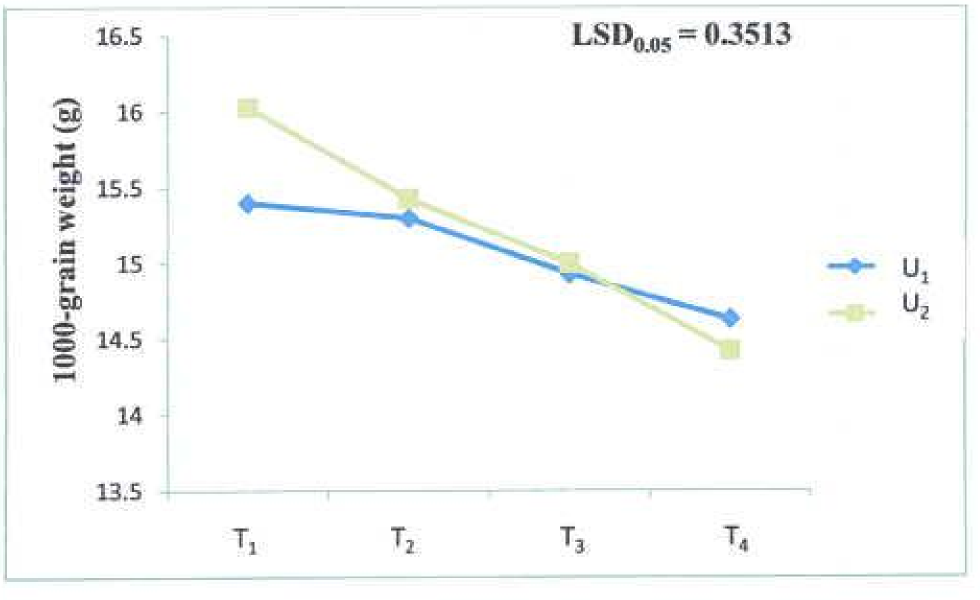
1000-grain weight of Late Aman (BINA sail) rice significantly influenced by different transplanting and re-transplanting dates (Figure 26). The highest 1000-grain weight (15.72 g) was recorded from T_1 (transplanted on 16 September) which was statistically similar with T_2 (re-transplanted on 23 September). On the other hand, re-transplanted on 07 October (T_4) showed the lowest result (14.52 g) (Appendix 3).

1000-grain weight of Late Aman (BINA sail) rice significantly influenced by the interaction effect of urea application methods and planting dates (Figure 27). The highest 1000-grain weight (16.03 g) was recorded from U_2T_1. On the other hand, U_2T_4 showed the lowest result (14.42 g) (Appendix 4).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 26. The effect of transplanting and re-transplanting dates on 1000-grain weight (mean of two urea application methods)

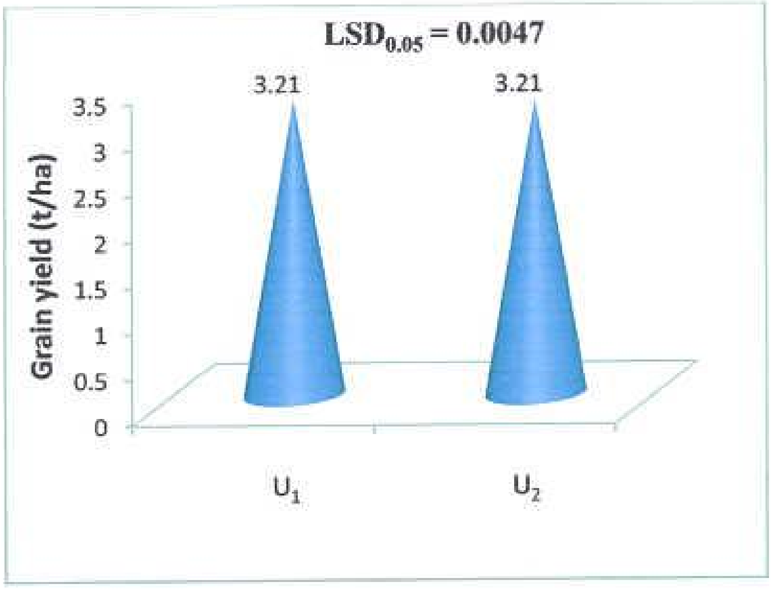


U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 27. The effect of urea application methods on 1000-grain weight under different transplanting and re-transplanting dates

4.10 Grain yield

Grain yield (t/ha) of BINA sail was similar (3.21 t ha^{-1}) in both top dressing of urea (U_1) and urea ball placement (U_2) due to the mean effect of different transplanting and re-transplanting dates (Figure 28 and Appendix 2).



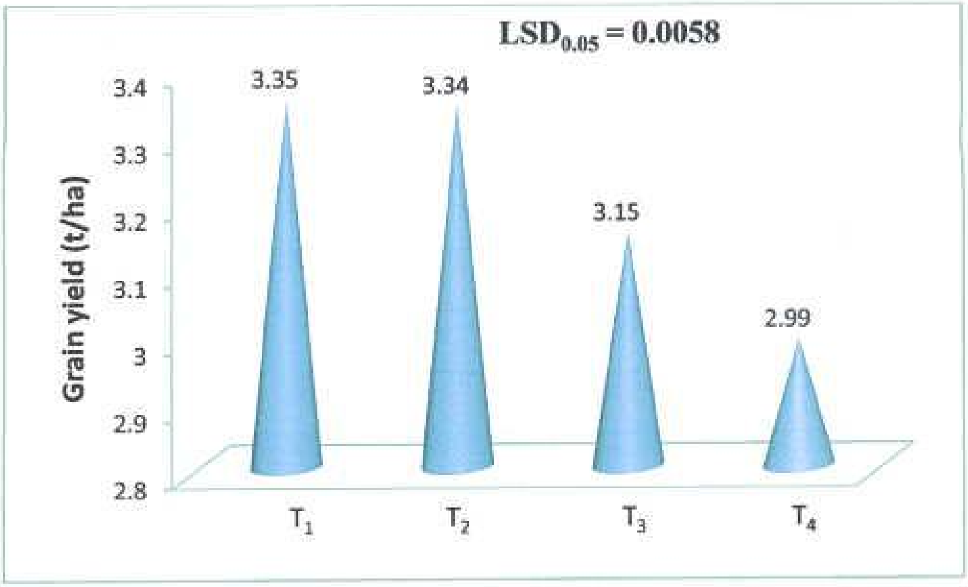
U_1- Urea topdressing, U_2- Urea ball placement

Figure 28. The effect of urea application methods on grain yield (mean of four transplanting and re-transplanting dates)

Transplanting and re-transplanting dates have significant influence on grain yield (Figure 29). The highest grain yield (3.35 t ha^{-1}) was obtained from T_1 (transplanted on 16 September) which was statistically similar with T_2 (re-transplanted on 23 September) while the lowest result (2.99 t ha^{-1}) was recorded from T_4 (re-transplanted on 07 October) (Appendix 3).

From Figure 30 and Appendix 4, it is clear that interaction effect of urea application methods and planting dates have significant effect on grain yield of

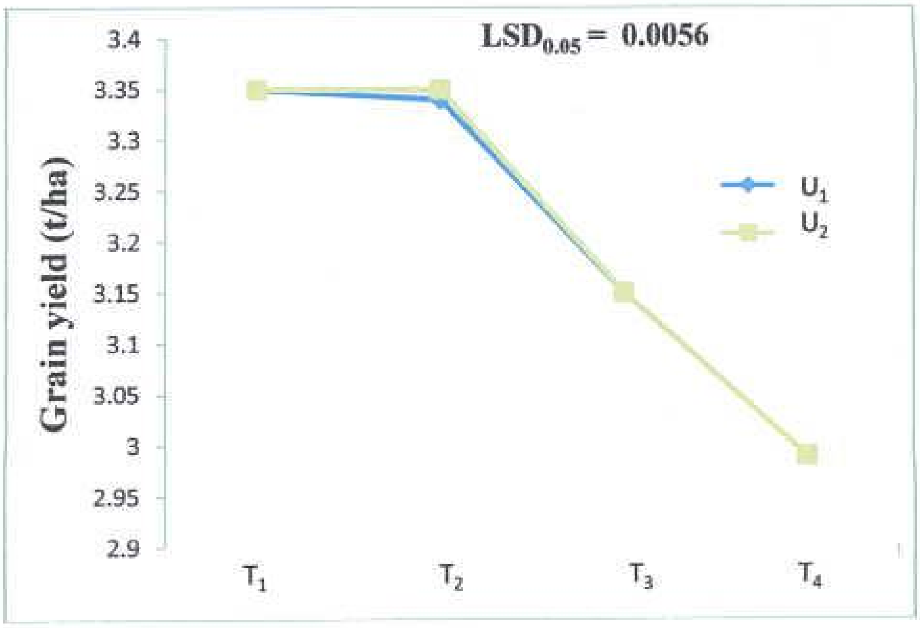
Late Aman (BINA sail) rice. The highest grain yield (3.35 t ha^{-1}) was obtained from U_1T_1, U_2T_1 and U_2T_2 while the lowest result (2.99 t ha^{-1}) was recorded from U_1T_4 and U_2T_4.



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 29. The effect of transplanting and re-transplanting dates on grain yield (mean of two urea application methods)

Hasanuzzaman *et al.* (2009) observed that USG produced superior yield than crystalline urea applied in rice crop. Nahar *et al.* (2009) found that grain yield decreased significantly with the delay of transplanting date. BRRI (1989) also reported similar results.



U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

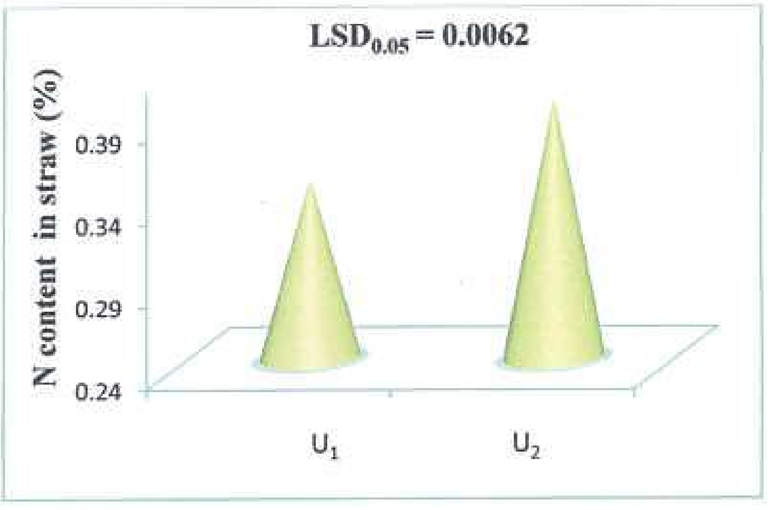
Figure 30. The effect of urea application methods on grain yield under different transplanting and re-transplanting dates

4.11 Chemical Composition

4.11.1 N content in straw

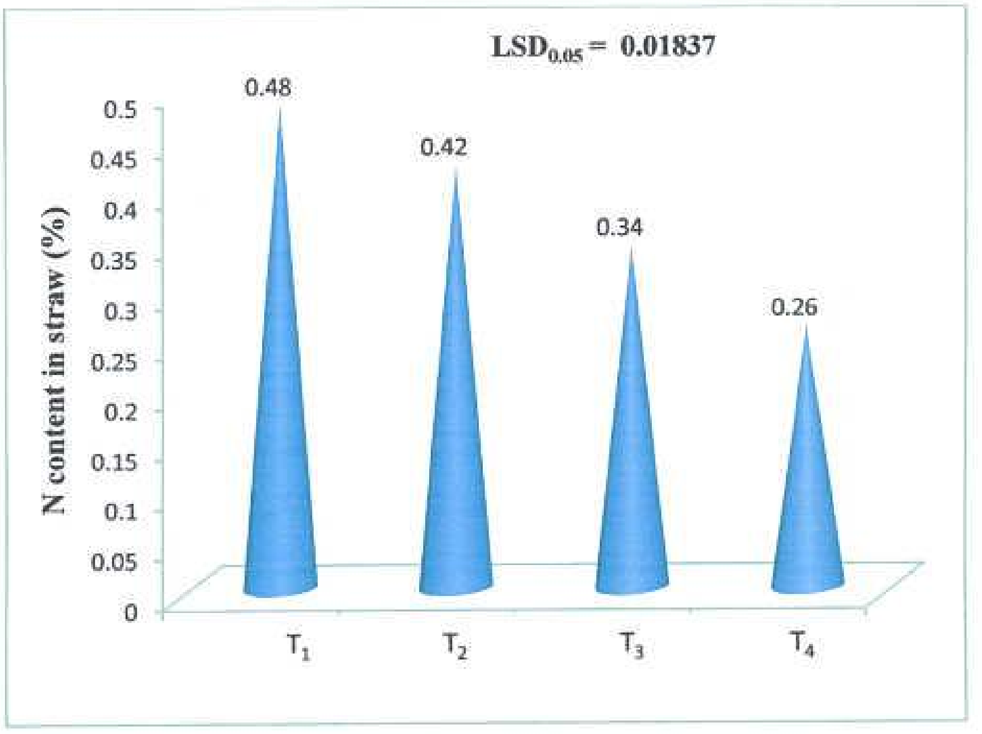
N content in straw showed a statistically significant difference due to the difference in application method of urea (Figure 31). The highest N content (0.40 %) was observed in straw from urea ball placement (U_2) and the lowest amount of N (0.35 %) found in straw for U_1 (urea topdressing) (Appendix 5).

It was observed from the results presented in Figure 32 and Appendix 6 that, transplanting and re-transplanting dates have significant influence on N content in straw. The highest N content (0.48 %) in straw was observed from T_1 (transplanted on 16 September) while re-transplanted on 07 October gave the lowest result (0.26 %).



U_1- Urea topdressing, U_2- Urea ball placement

Figure 31. The effect of urea application methods on N content in straw (mean of four transplanting and re-transplanting dates)

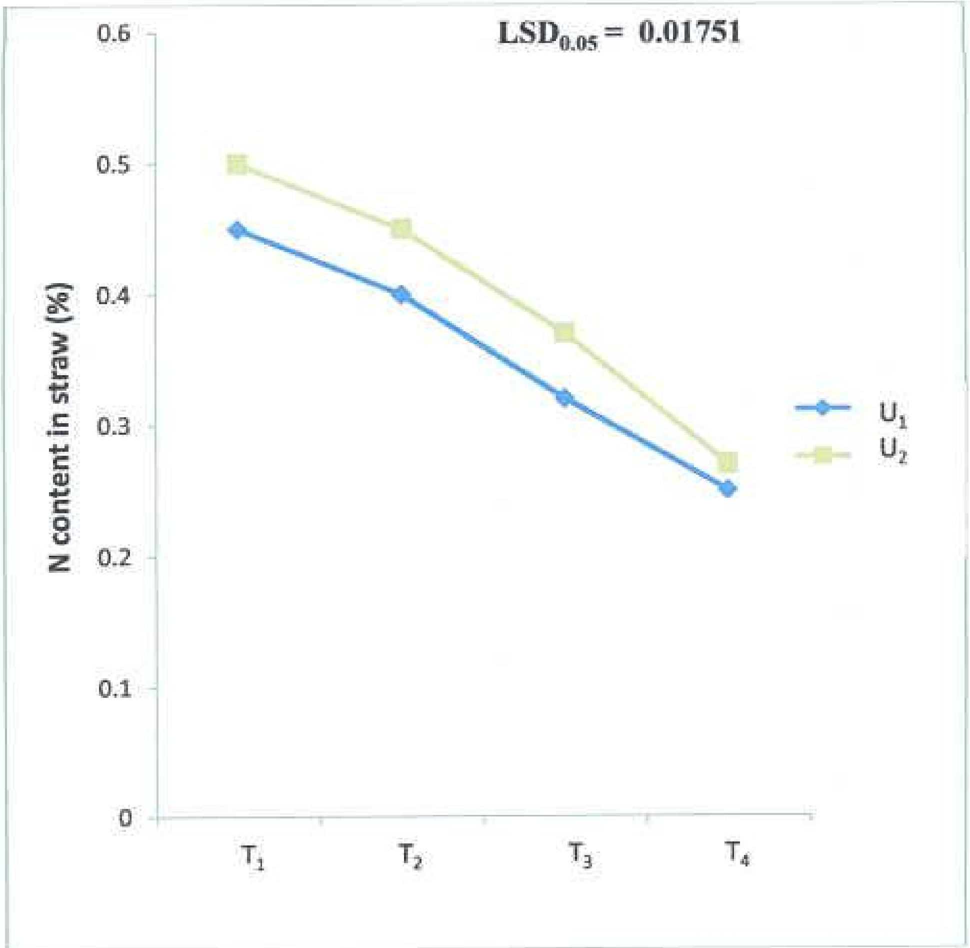


T_1 : Transplanted on 16 September, T_2 : Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 32. The effect of transplanting and re-transplanting dates on N content in straw (mean of two urea application methods)

N content in straw varied significantly due to the interaction effect of urea application methods and planting dates (Figure 33). The highest N content in straw (0.50 %) was observed from U_2T_1 while the lowest result (0.25 %) was recorded from U_1T_4 (Appendix 7).



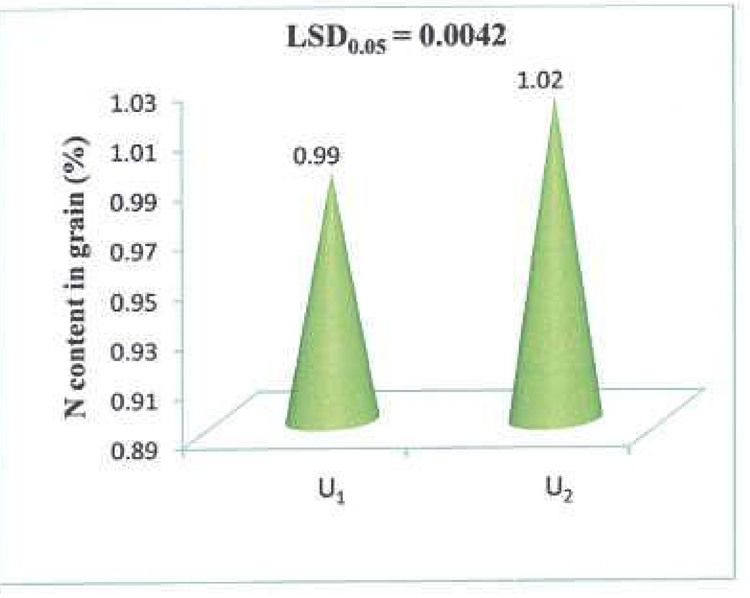
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 33. The effect of urea application methods on N content in straw under different transplanting and re-transplanting dates

A significant increase in N content in rice straw due to the application of urea granular fertilizers has been reported by Azim (1999).

4.11.2 N content in grain

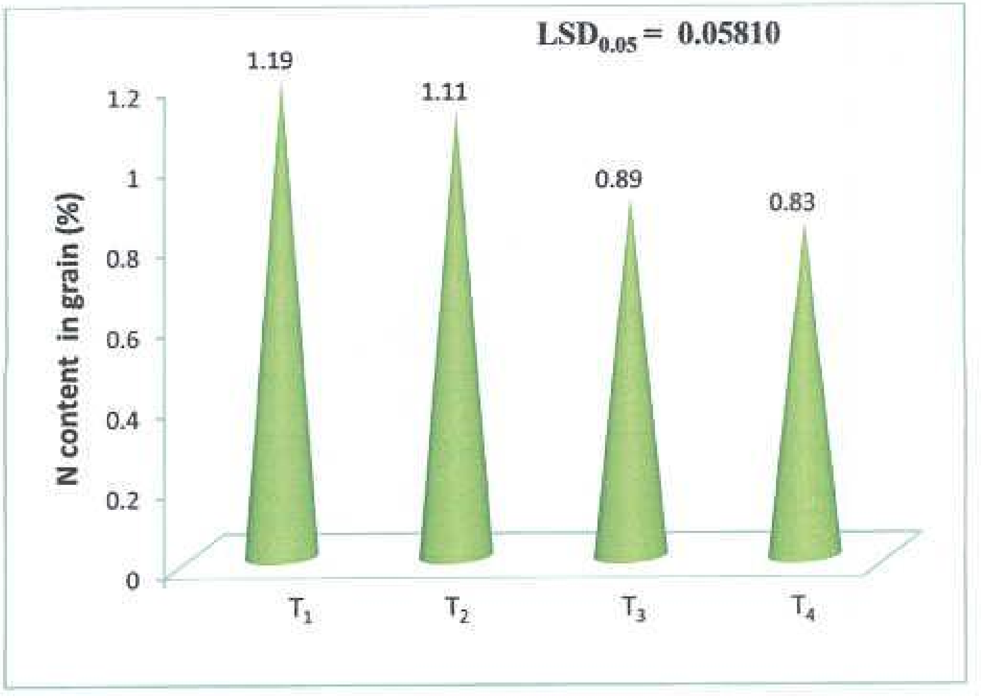
A statistically significant variation was recorded due to the difference in application method of urea for N content in grain (Figure 34). The highest N content (1.02 %) in grain was observed from urea ball placement (U_2) and the lowest N content (0.99 %) in grain was found for U_1 (topdressing of urea) (Appendix 5).



U_1- Urea topdressing, U_2- Urea ball placement

Figure 34. The effect of urea application methods on N content in grain (mean of four transplanting and re-transplanting dates)

A significant variation was observed due to the difference in transplanting and re-transplanting dates for N content in grain (Figure 35). The highest N content (1.19 %) in grain was obtained from T_1 (transplanted on 16 September). The lowest N content (0.83%) in grain was recorded for T_4 (re-transplanted on 07 October) which have statistically no difference with T_3 (re-transplanted on 30 September) (Appendix 6).

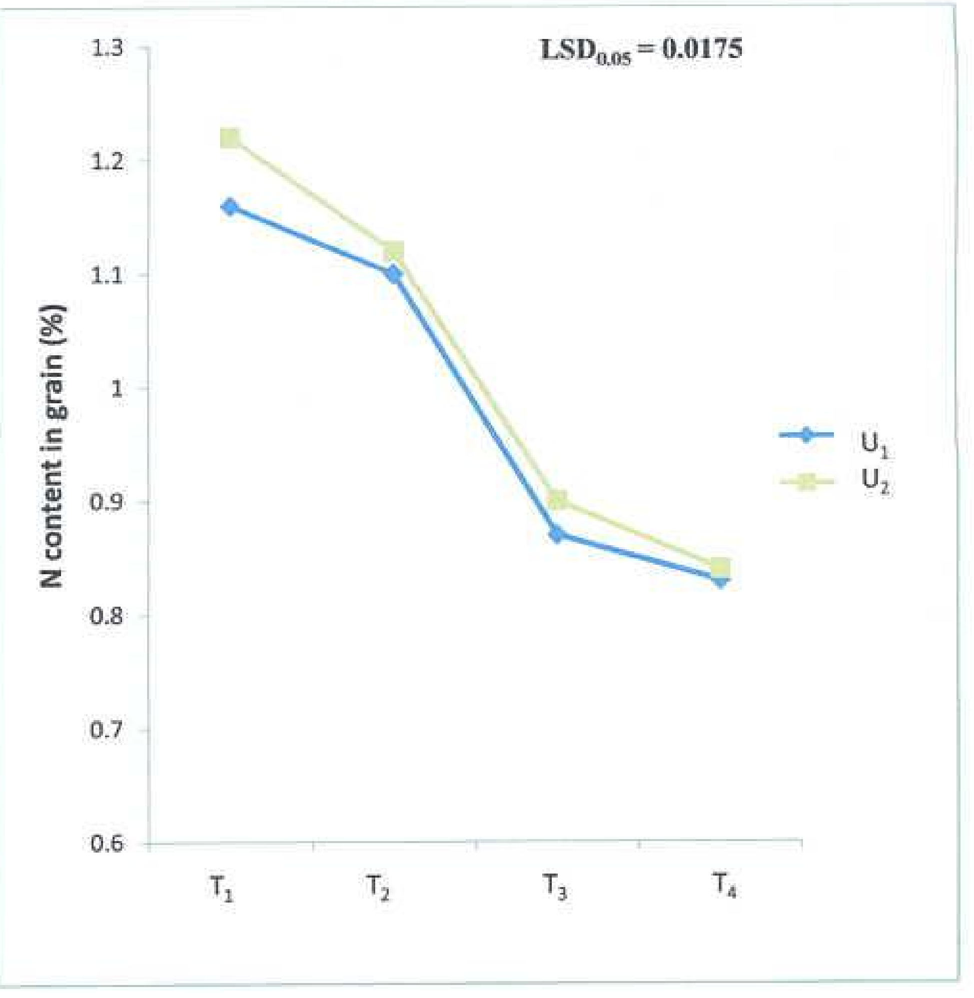


T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 35. The effect of transplanting and re-transplanting dates on N content in grain (mean of two urea application methods)

A significant variation was observed due to the interaction effect of urea application methods and planting dates on N content in grain (Figure 36). The highest N content (1.22 %) in grain was observed from U_2T_1. On the other hand, U_1T_4 showed the lowest result (0.83 %) which was statistically similar with U_2T_4 (Appendix 7).

A significant increase in N content in rice grain and straw due to the application of 100 kg N ha^{-1} from urea super granule has been supported by Rambabu *et al.* (1983).

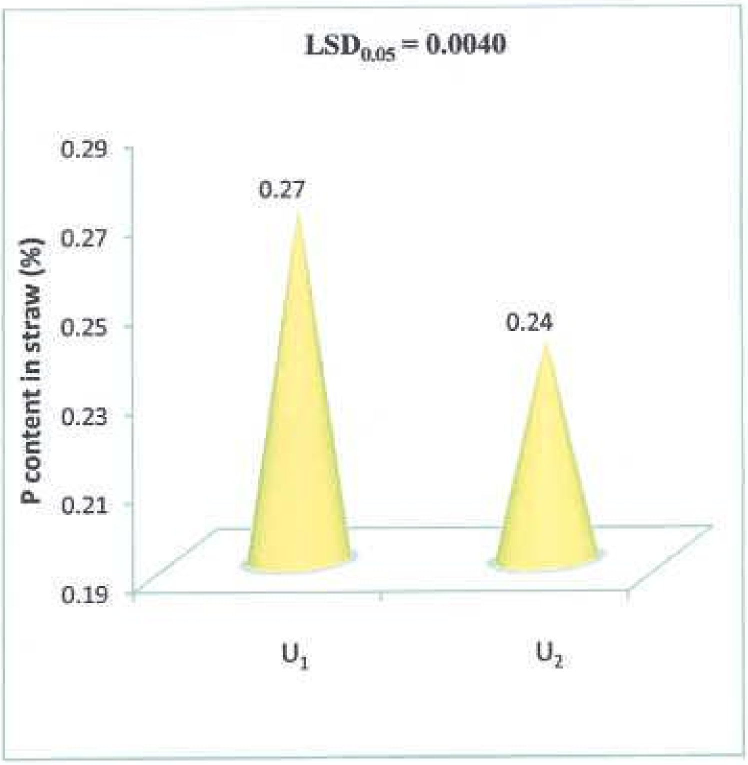


U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 36. The effect of urea application methods on N content in grain under different transplanting and re-transplanting dates

4.11.3 P content in straw

A significant variation was observed due to the difference in application method of urea for P content in straw (Figure 37). In straw, the highest P content (0.27 %) was observed from U_1 (topdressing of urea) while for ball placement (U_2), the value was 0.24 % (Appendix 5).

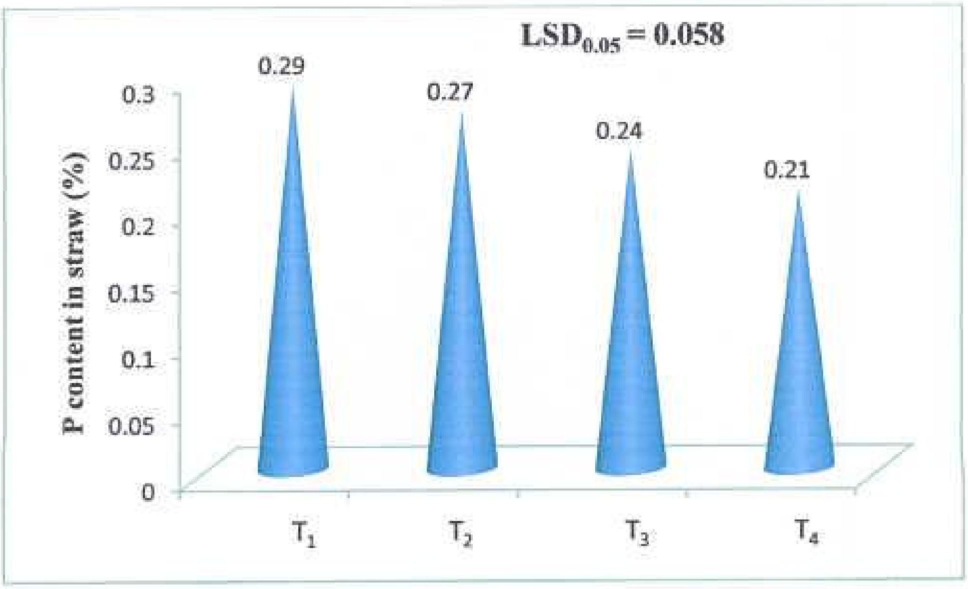


U_1- Urea topdressing, U_2- Urea ball placement

Figure 37. The effect of urea application methods on P content in straw (mean of four transplanting and re-transplanting dates)

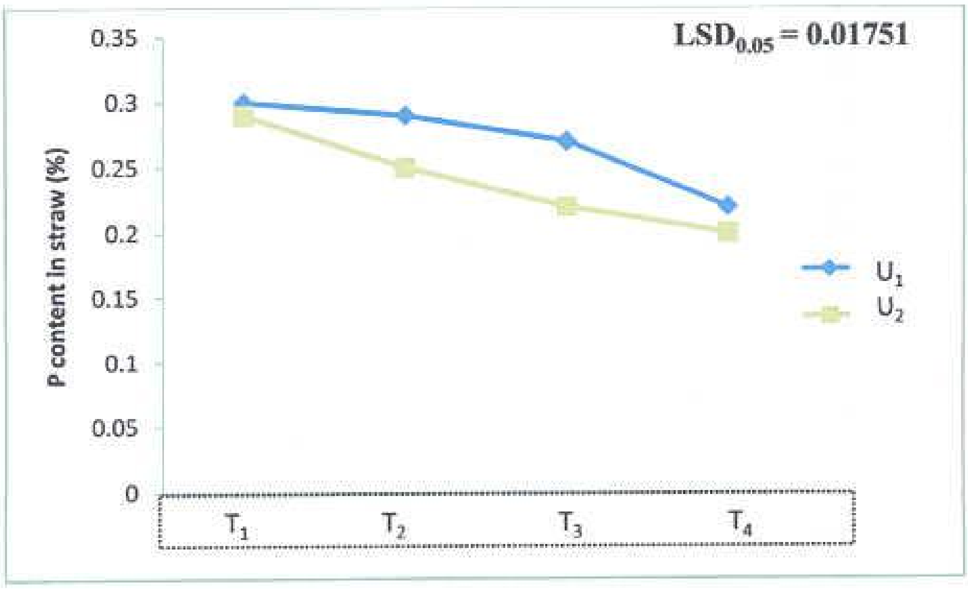
P content in straw varied significantly due to the effect of different transplanting and re-transplanting dates (Figure 38). P content in straw was recorded maximum (0.29 %) in T_1 (transplanted on 16 September) while minimum (0.21 %) at T_4 (re-transplanted on 07 October) (Appendix 6).

From Figure 39, it is clear that interaction effect of urea application methods and planting dates have significant effect on P content in straw. The highest P content (0.30 %) was observed in straw from U_1T_1 while the U_2T_4 gave the lowest result (0.20 %) which was statistically identical with U_1T_4 and U_2T_3 (Appendix 7).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 38. The effect of transplanting and re-transplanting dates on P content in straw (mean of two urea application methods)



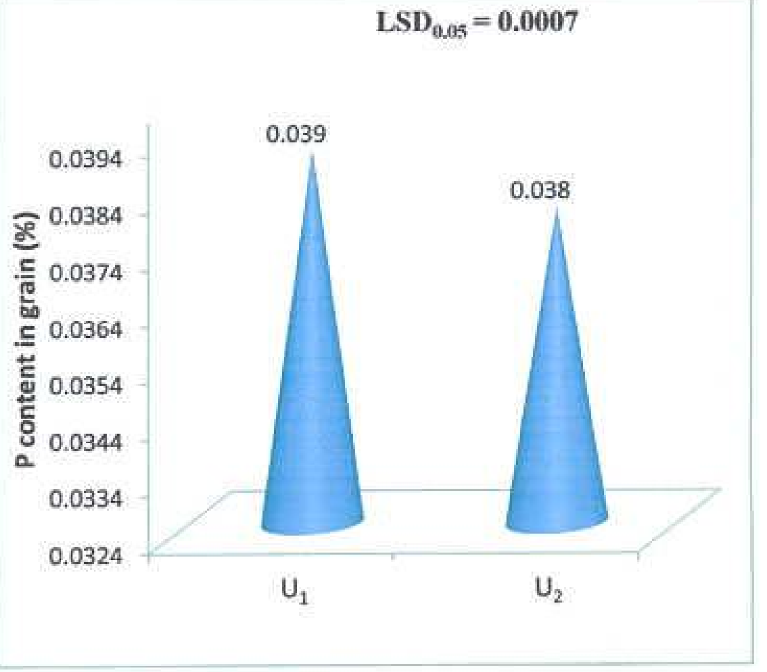
U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 39. The effect of urea application methods on P content in straw under different transplanting and re-transplanting dates

4.11.4 P content in grain

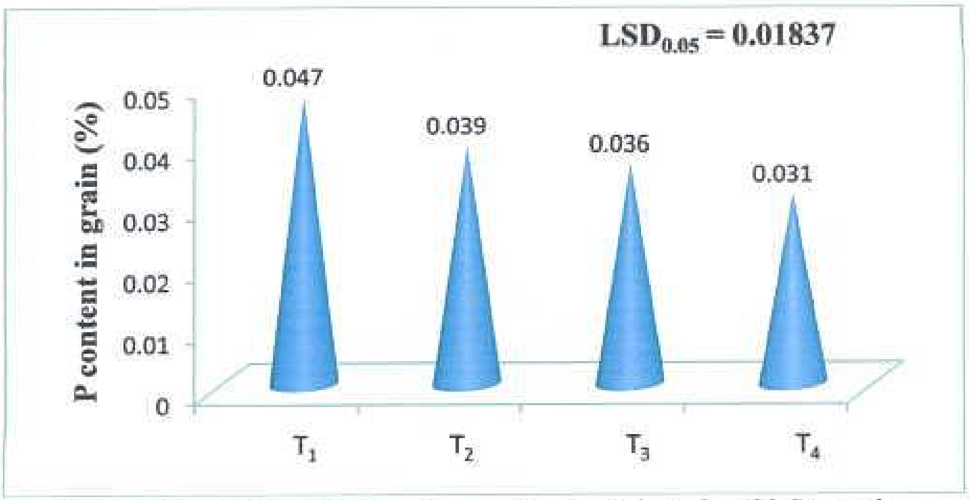
A significant variation was observed due to the difference in application method of urea for P content in grain (Figure 40). In grain, the highest P content (0.39 %) was observed from U_1 (topdressing of urea) while for ball placement (U_2), the value was 0.38 % (Appendix 5).

P content in grain didn't varied significantly due to the effect of different transplanting and re-transplanting dates (Figure 41 and Appendix 6). In grain, the highest P content (0.047 %) was observed from T_1 (transplanted on 16 September) while it was lowest (0.030 %) for T_4 (re-transplanted on 07 October).



U_1- Urea topdressing, U_2- Urea ball placement

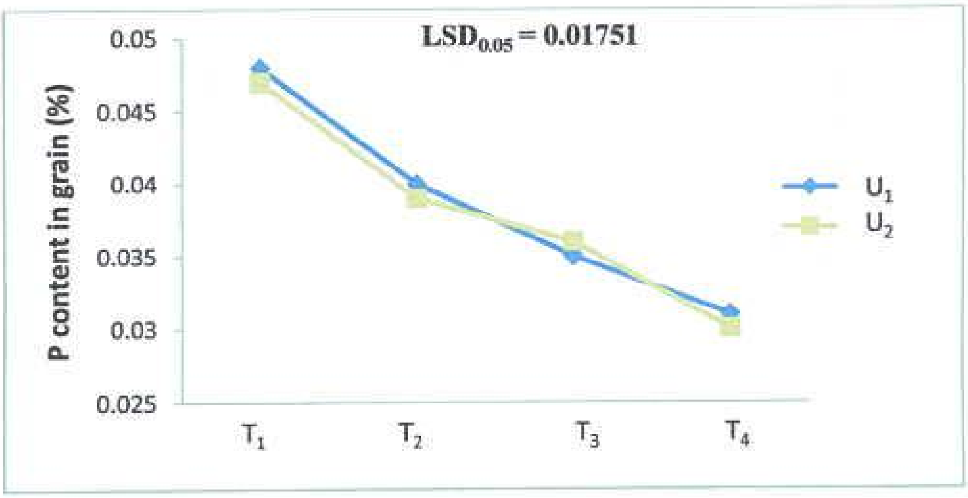
Figure 40. The effect of urea application method on P content in grain (mean of four transplanting and re-transplanting dates)



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 41. The effect of transplanting and re-transplanting dates on content in grain (mean of two urea application methods)

No significant variation was found due to the interaction effect of urea application methods and planting dates on P content in grain (Figure 42 and Appendix 7). In grain the highest P content (0.048 %) was observed from U_1T_1 and lowest P content (0.030 %) was observed from U_2T_4.

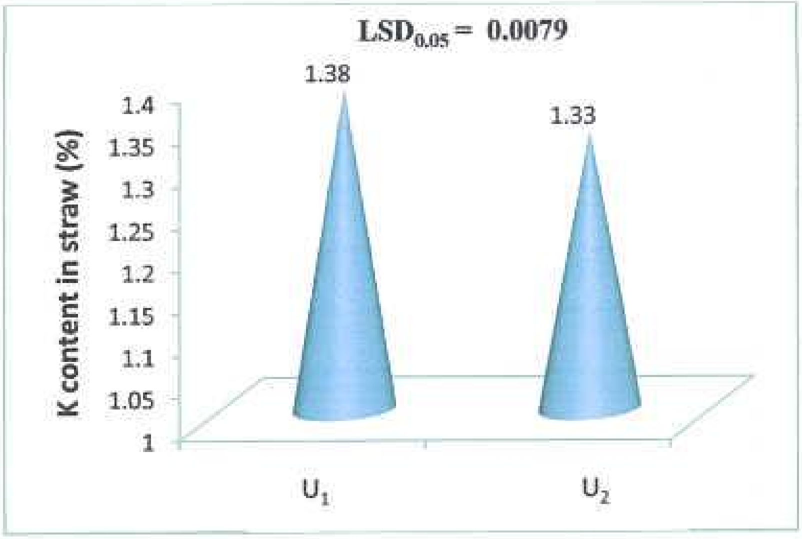


U_1- Urea topdressing, U_2- Urea ball placement
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September
T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 42. The effect of urea application methods on P content in grain under different transplanting and re-transplanting dates

4.11.5 K content in straw

Potassium content (%) in straw of BINA sail significantly differed by the urea top dress and ball placement (Figure 43). The highest K content (1.38 %) in straw was observed from U_1 (topdressing of urea) while for ball placement (U_2), the K content was 1.33 % (Appendix 5).

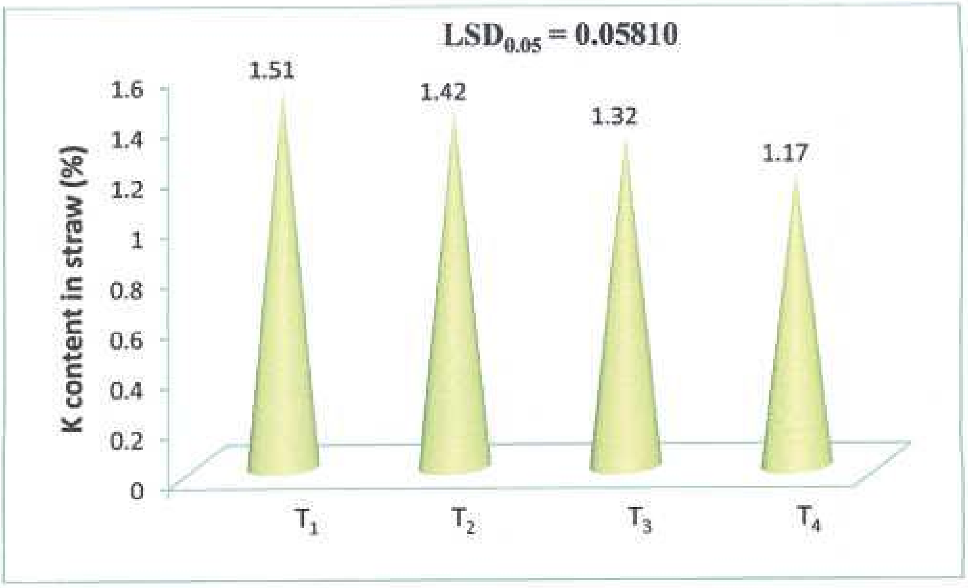


U_1- Urea topdressing, U_2- Urea ball placement

Figure 43. The effect of urea application methods on K content in straw (mean of four transplanting and re-transplanting dates)

K content in straw also showed a statistically significant difference due to the different transplanting and re-transplanting dates (Figure 44). The highest K content (1.51 %) in straw was observed from T_1 (transplanted on 16 September) while re-transplanted on 07 October (T_4) gave lowest result (1.17 %) (Appendix 6).

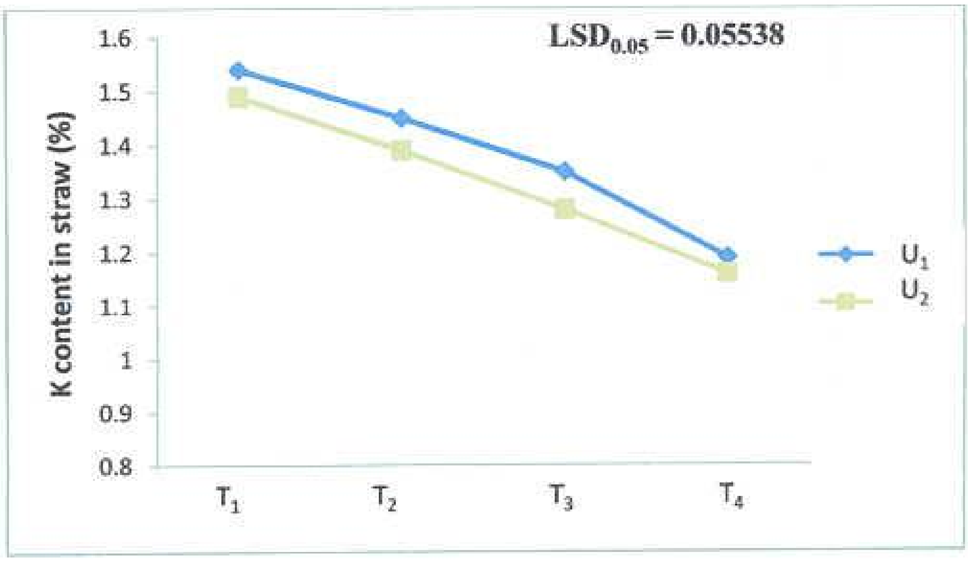
K content in straw varied significantly due to the interaction effect of urea application methods and planting dates (Figure 45). The highest K content (1.54 %) in straw was observed from U_1T_1 while the U_2T_4 gave lowest content (1.16 %) of K in straw which was statistically similar with U_1T_4 (Appendix 7).



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 44. The effect of transplanting and re-transplanting dates on K content in straw (mean of two urea application methods)



U_1- Urea topdressing, U_2- Urea ball placement

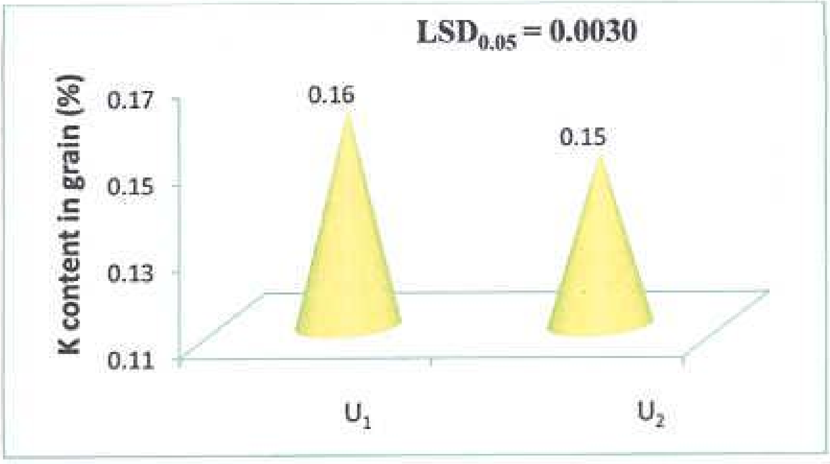
T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 45. The effect of urea application methods on K content in straw under different transplanting and re-transplanting dates

4.11.6 K content in grain

No significant difference was obtained due to the difference in application method of urea in terms of K content in grain (Figure 46). In grain, the highest K content (0.16 %) was observed from U_1 (topdressing of urea) while for ball placement (U_2), the value was 0.15 % (Appendix 5).

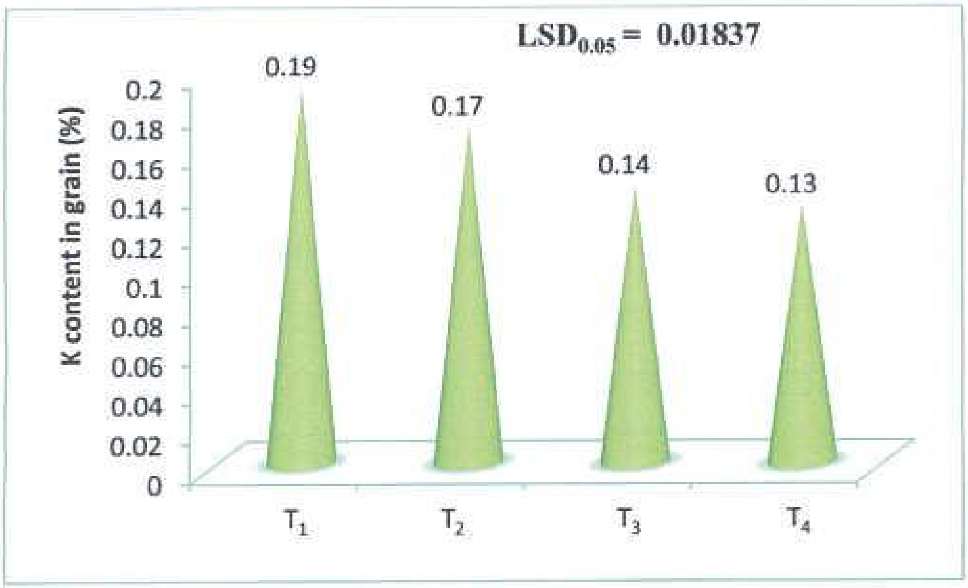


U_1- Urea topdressing, U_2- Urea ball placement

Figure 46. The effect of urea application methods on K content in grain (mean of four transplanting and re-transplanting dates)

K content in grain showed a statistically significant variation due to the difference in transplanting and re-transplanting dates (Figure 47). In grain the highest K content (0.19 %) was observed from T_1 (transplanted on 16 September); while it was lowest (0.13 %) for T_4 (re-transplanted on 07 October) which has statistically no difference with T_3 (re-transplanted on 30 September) (Appendix 6).

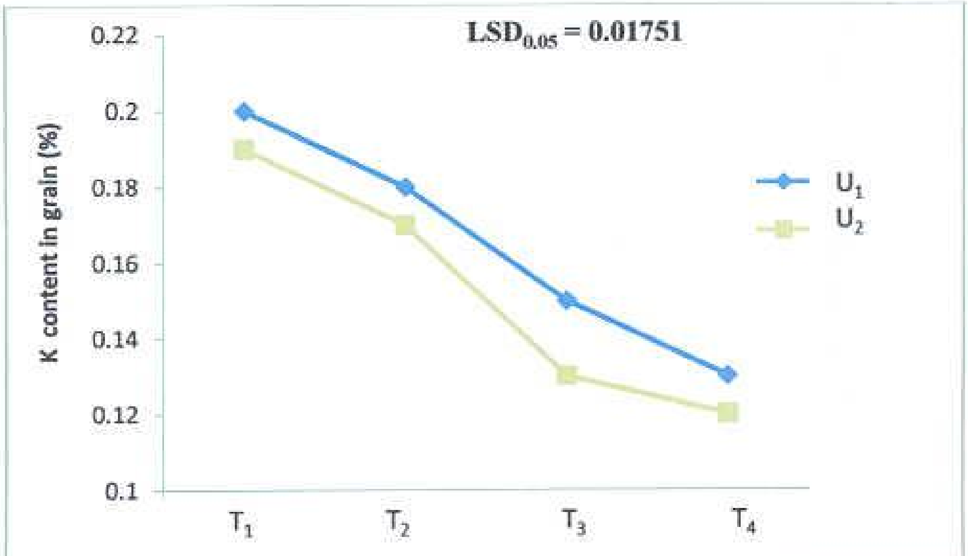
K content in grain varied significantly due to the interaction effect of urea application methods and planting dates (Figure 48 and Appendix 7). In grain the highest K content (0.20 %) was observed from U_1T_1 and lowest K content (0.12 %) was observed from U_2T_4 which was statistically similar with U_1T_4.



T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 47. The effect of transplanting and re-transplanting dates on K content in grain (mean of two urea application methods)



U_1- Urea topdressing, U_2- Urea ball placement

T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

Figure 48. The effect of urea application methods on K content in grain under different transplanting and re-transplanting dates

CHAPTER 5

SUMMARY AND CONCLUSIONS

The present work was conducted at Barga village under Kalihati upazilla of Tangail district during the period from August to December, 2011 to find out the effects of urea topdressing and ball placement on the growth, yield and N,P,K nutrients content of transplanted and re-transplanted Aman rice (BINA sail). The experiment consisted of two urea application methods (U_1 = Urea topdressing and U_2 = Urea ball placement) and 4 transplanting and re-transplanting dates (T_1 = 16 September, T_2 = 23 September, T_3 = 30 September and T_4 = 07 October). The experiment was laid out in a RCBD design with three replications.

Urea application methods showed significant variation in case of growth, yield and nutrient content of transplanted and re-transplanted Aman rice (BINA sail). The tallest plant (110.17 cm) was obtained from U_1 (Urea topdressing) while U_2 (Urea ball placement) treatment was not far behind. The highest number of total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, spikelet panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1} and the longest panicle was found from U_2. 1000-grain weight was comparatively higher (15.22 g) in urea ball placement (U_2) than the topdressing of urea (15.06 g). Grain yield of BINA sail was similar in both topdressing of urea (U_1) and urea ball placement (U_2) due to the mean effect of different transplanting and re-transplanting dates. The highest N content in straw (0.40 %) and grain (1.02 %) were observed from urea ball placement (U_2). In both straw and grain; the highest P & K content was observed from U_1

(topdressing of urea). The highest N content in grain was observed from urea ball placement (U_2).

Growth, yield and N,P,K nutrients content of transplanted and re-transplanted Aman rice (BINA sail) varied significantly in most of the cases due to the effect of different planting dates. Plant height, number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$, spikelet $panicle^{-1}$ and filled grains $panicle^{-1}$ and panicle length were found highest in T_2 (re-transplanted on 23 September). The highest number of non-effective tillers $hill^{-1}$ and unfilled grains $panicle^{-1}$ were recorded in the last date of re-transplanting (T_4 = re-transplanted on 07 October) while the lowest values were found in T_2. For plant height, number of spikelet $panicle^{-1}$ and unfilled grains $panicle^{-1}$, there was no significant difference between T_1 (transplanted on 16 September) and T_2. The highest 1000-grain weight and grain yield was recorded from T_1 which was statistically similar with T_2. On the other hand the last re-transplanted on 07 October (T_4) showed the lowest result (14.53 g) for both 1000-grain weight and grain yield. For N, P and K contents in both straw and grain, the highest results were recorded in T_1 followed by T_2 while T_4 gave the lowest.

Plant height, number of effective tillers $hill^{-1}$, spikelet $panicle^{-1}$ and filled grains $panicle^{-1}$ differed significantly due to the interaction of urea application methods and planting dates of late Aman cultivar BINA sail. The tallest plant was obtained from U_1T_2 (topdressing of urea and re-transplanted on 23 September) which was statistically similar with U_1T_1 and U_2T_2. On the other hand, U_2T_4 (urea ball placement and re-transplanted on 07 October) produced the shortest one which was statistically similar with U_1T_4. The highest number of effective tillers $hill^{-1}$

was found from U_2T_2 which was statistically similar with U_1T_2, U_1T_1 and U_2T_1. On the other hand, U_1T_4 produced the lowest number of effective tillers hill^{-1}. The highest number of spikelet panicle^{-1} was recorded from U_2T_2 while the lowest was recorded from U_2T_4. The highest number of filled grain panicle^{-1} was recorded from U_2T_2 while the lowest was recorded from U_2T_4 which was statistically similar with U_1T_4. The highest 1000-grain weight was recorded from U_2T_1 while U_2T_4 showed the lowest result. The highest grain yield (3.35 t/ha) was obtained from U_1T_1, U_2T_1 and U_2T_2 while the lowest result (2.99 t/ha) was recorded from U_1T_4 and U_2T_4. N, P and K content for both straw and grain decreased with later dates of transplantation in topdressing and ball placement of urea. The highest N content in straw was observed from U_2T_1 while the lowest result was recorded from U_1T_4. The P content in straw was higher in U_1T_1 while the U_2T_4 gave the lowest result. The highest K content in straw was observed from U_1T_1 while the U_2T_4 gave lowest content of K in straw which was statistically similar with U_1T_4. The highest N content in grain (1.22 %) was observed from U_2T_1 while U_1T_4 showed the lowest result which was statistically similar with U_2T_4. In grain the highest P content (0.047 %) was observed from U_1T_1 and lowest P content was observed from U_2T_4. The highest K content in grain was observed from U_1T_1 and the lowest was observed from U_2T_4 which was statistically similar with U_1T_4.

It appeared from the above results that different urea application methods and transplanting and re-transplanting dates have significant effect on growth, yield and nutrient (N, P, K) contents of T. Aman rice BINA sail. Urea ball placement was more efficient compare to topdressing of urea except vegetative growth. With delay in transplanting the yield of BINA sail reduced but still it was possible to get some sort of economic return by escaping the late flood.

Based on the findings of the experiment, the following recommendations may be made :

- Urea ball or super granules should be used instead of topdressing to ensure proper and adequate N nutrient supply for rice plants.
- In flood prone areas, it may be possible to get some yield by late re-transplanting of BINA sail.

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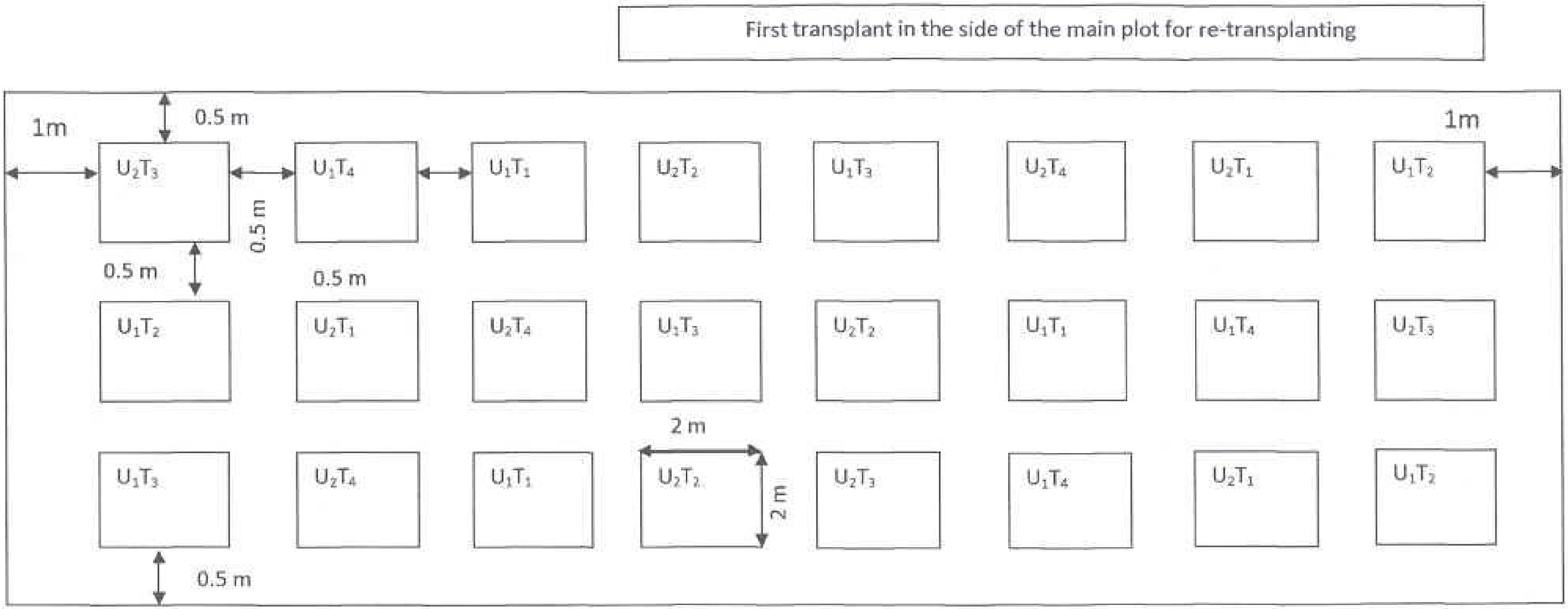
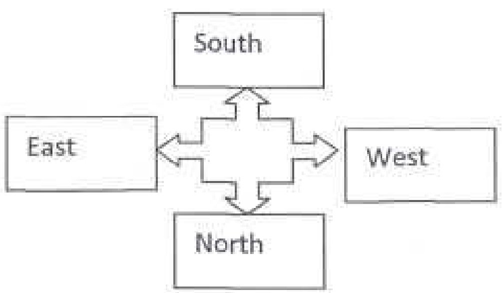
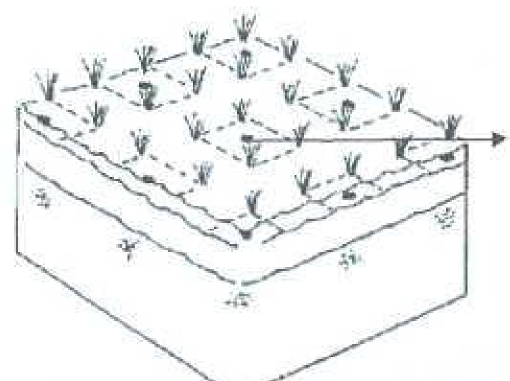
CHAPTER 7

APPENDICES

Appendix 1. Layout of the experimental field







Urea ball placement

Appendix 2. The effect of different application methods of urea on various growth and yield parameters of Aman rice cv. BINA sail (mean of 4 transplantation treatments)

Urea application method	Plant height	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length	Spikelet number panicle^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	1000-grain weight	Grain Yield (t/ha)
U_1	110.17	15.55	12.21	3.33	24.52	195.35	154.53	40.82	15.06	3.21
U_2	109.85	15.99	12.59	3.40	25.00	198.45	156.08	42.36	15.22	3.21
$s_{\bar{y}}$ value	0.5411	0.1721	0.1969	0.1916	0.1021	2.3437	2.5838	0.3589	0.0818	0.0047
Significant level	*	**	**	*	**	**	*	**	**	NS
CV %	2.17	6.58	8.03	23.25	4.14	4.11	3.52	8.17	1.31	0.67

U_1- Topdressing of urea, U_2- Urea ball placement

** - Significant at 1 % level

* - Significant at 5 % level

NS- Non-significant

Appendix 3. The effect of different transplanting and re-transplanting dates on various growth and yield parameters of Aman rice cv. BINA sail (mean of 2 Urea application treatments)

Transplantation treatments	Plant height	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Spikelet number panicle^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	1000-grain weight (g)	Grain Yield (t/ha)
T_1	111.80 a	16.18 ab	13.05 ab	3.13 c	24.86 ab	200.31 a	158.83 ab	40.98 b	15.72 a	3.35 a
T_2	112.51 a	16.48 a	13.30 a	3.18 bc	25.47 a	202.51 a	163.00 a	40.01 b	15.37 a	3.34 a
T_3	108.46 b	15.23 b	11.93 bc	3.30 b	24.53 ab	195.38 ab	153.73 b	41.65 ab	14.97 ab	3.15 b
T_4	107.28 b	15.18 b	11.33 c	3.85 a	24.18 b	189.40 b	145.66 c	43.73 a	14.52 b	2.99 c
$LSD_{0.05}$	1.223	1.219	1.136	0.1643	1.822	9.39	6.238	2.629	0.7946	0.0058
Significant level	**	**	**	**	**	**	**	**	**	**
CV %	2.17	6.58	8.03	23.25	4.14	4.11	3.52	8.17	1.31	0.67

T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

** - Significant at 1% level

Appendix 4. The effect of different application methods of urea on growth and yield parameters of Aman rice cv. BINA sail due to different transplanting and re-transplanting dates

Urea Application Method	Transplantation treatments	Plant height	Number of total tillers $hill^{-1}$	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$	Panicle length (cm)	Spikelet number $panicle^{-1}$	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	1000-grain weight (g)	Grain Yield (t/ha)
U_1	T_1	112.23 a	16.26	13.16 a	3.10	24.56	198.86 ab	157.66 ab	40.20	15.40 b	3.35 a
	T_2	112.63 a	16.40	13.20 a	3.20	24.86	198.10 ab	160.66 ab	38.43	15.30 bc	3.34 a
	T_3	108.26 ab	14.86	11.63 ab	3.23	24.43	194.53 ab	153.13 bc	41.40	14.93 de	3.15 b
	T_4	107.56 b	14.66	10.86 b	3.80	24.23	189.93 b	146.66 c	43.26	14.63 ef	2.99 d
U_2	T_1	111.36 ab	16.10	12.93 a	3.16	25.16	201.76 ab	160.00 ab	41.76	16.03 a	3.35 a
	T_2	112.40 a	16.56	13.40 a	3.16	26.06	206.93 a	165.33 a	41.60	15.43 b	3.35 a
	T_3	108.66ab	15.60	12.23 ab	3.36	24.63	196.23 ab	154.33 bc	41.90	15.00 cd	3.15 c
	T_4	107.00 b	15.70	11.80 ab	3.90	24.13	188.86 b	144.66 c	44.20	14.42 f	2.99 d
$LSD_{0.05}$		4.25	1.847	1.772	1.393	1.822	14.38	9.728	6.048	0.3513	0.0056
Significant level		**	NS	**	NS	NS	**	**	NS	**	**
CV %		2.17	6.58	8.03	23.25	4.14	4.11	3.52	8.17	1.31	0.67

U_1- Topdressing of urea, U_2- Urea ball placement

T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

** - Significant at 1% level

NS- Non-significant

Appendix 5. The effect of different application methods of urea on nutrient content in grain and straw of Aman rice cv. BINA sail (mean of 4 transplantation treatments)

Urea application method	**N concentration in straw (%)**	**N concentration in grain (%)**	**P concentration in straw (%)**	**P concentration in grain (%)**	**K concentration in straw (%)**	**K concentration in grain (%)**
U_1	0.35	0.99	0.27	0.039	1.38	0.16
U_2	0.40	1.02	0.24	0.038	1.33	0.15
$s_{\bar{y}}$ value	0.0062	0.0042	0.0040	0.0007	0.0079	0.0030
Significant level	**	**	**	**	**	**
CV %	5.67	1.43	5.41	5.89	2.02	6.40

U_1- Topdressing of urea, U_2- Urea ball placement

** - Significant at 1 % level

Appendix 6. The effect of different transplanting and re-transplanting dates on nutrient content in grain and straw of Aman rice cv. BINA sail (mean of 2 Urea application treatments)

Transplantation treatments	**N concentration in straw (%)**	**N concentration in grain (%)**	**P concentration in straw (%)**	**P concentration in grain (%)**	**K concentration in straw (%)**	**K concentration in grain (%)**
T_1	0.48 a	1.19 a	0.29 a	0.047	1.51 a	0.19 a
T_2	0.42 b	1.11 b	0.27 ab	0.039	1.42 b	0.17 b
T_3	0.34 c	0.89 c	0.24 ab	0.036	1.32 c	0.14 c
T_4	0.26 d	0.83 c	0.21 b	0.031	1.17 d	0.13 c
$LSD_{0.05}$	0.01837	0.05810	0.05810	0.01837	0.05810	0.01837
Significant level	**	**	**	NS	**	**
CV %	5.67	1.43	5.41	5.89	2.02	6.40

T_1 : Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3 : Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

** - Significant at 1% level

NS- Non-significant

Appendix 7. The effect of different application methods of urea on nutrient content in grain and straw of Aman rice cv. BINA sail due to different transplanting and re-transplanting dates

Urea Application Method	Transplantation treatments	N concentration in straw (%)	N concentration in grain (%)	P concentration in straw (%)	P concentration in grain (%)	K concentration in straw (%)	K concentration in grain (%)
U_1	T_1	0.45 b	1.16 b	0.30 a	0.048	1.54 a	0.20 a
	T_2	0.40 c	1.10 d	0.29 ab	0.040	1.45 b	0.18 bc
	T_3	0.32 e	0.87 f	0.27 b	0.035	1.35 c	0.15 d
	T_4	0.25 g	0.83 g	0.22 d	0.031	1.19 e	0.13 e
U_2	T_1	0.50 a	1.22 a	0.29 ab	0.047	1.49 ab	0.19 ab
	T_2	0.45 b	1.12 c	0.25 c	0.039	1.39 c	0.17 c
	T_3	0.37 d	0.90 e	0.22 d	0.036	1.28 d	0.13 de
	T_4	0.27 f	0.84 g	0.20 d	0.030	1.16 e	0.12 e
$LSD_{0.05}$		0.01751	0.01751	0.01751	0.01751	0.05538	0.01751
Significant level		**	**	**	NS	**	**
CV %		5.67	1.43	5.41	5.89	2.02	6.40

U_1- Topdressing of urea, U_2- Urea ball placement

T_1: Transplanted on 16 September, T_2 :Re-transplanted on 23 September

T_3: Re-transplanted on 30 September, T_4 : Re-transplanted on 07 October

** - Significant at 1% level

NS- Non-significant