EFFECT OF FOLIAR APPLICATION OF UREA ON GROWTH AND YIELD OF BORO RICE

A THESIS

BY

MD. ABDUL ALIM
Student ID: 1605320
Session: 2016-2017
Semester: January-June, 2018

MASTER OF SCIENCE

IN

AGRONOMY

DEPARTMENT OF AGRONOMY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200

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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR-5200

JUNE, 2018

Dedicated

To My

Respectable

Parents

&

Teachers

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June, 2018 *The Author*

EFFECT OF FOLIAR APPLICATION OF UREA ON GROWTH AND YIELD OF BORO RICE

ABSTRACT

The experiment was conducted at the research field, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur during January to May, 2017 to find out the effect of foliar application of urea on the yield traits and yield of boro rice cv. BRRI dhan28. The experiment was laid out in Randomized Complete Block Design with three replications. The one factorial experiment was consisted of 10 treatments viz. T_1= N_0 (Control i.e. no urea used), T_2= N_{50+10}% (50% urea as 2 times top dressing and 10% urea as 2 times foliar spray were applied), T_3= N_{50+15}% (50% urea as 2 times top dressing and 15% urea as 3 times foliar spray were applied), T_4= N_{50+20}% (60% urea as 2 times top dressing and 20% urea as 3 times foliar spray were applied), T_5= N_{60+10}% (60% urea as 2 times top dressing and 10% urea as 2 times foliar spray were applied), T_6= N_{60+15}% (60% urea as 2 times top dressing and 15% urea as 3 times foliar spray were applied), T_7= N_{60+20}% (70% urea as 2 times top dressing and 20% urea as 2 times foliar spray were applied), T_8= N_{70+10}% (70% urea as 2 times top dressing and 10% as 3 times foliar spray were applied), T_9 all urea were applied as traditional method (33.33% during land preparation, 33.33% after 25 DAT and rest 33.33% urea at 40 DAT). T_{10} all urea were applied as traditional method (as T_9 and 10% as 2 times foliar applications as treatment T_2).The recommended dose of urea, TSP, MOP, gypsum, $ZnSO_4$ and borax @ 250, 75, 100, 75, 10 and 5 kg ha^{-1} ,respectively. All fertilizers except urea were applied during land preparation. The results revealed that most of the parameters showed significant difference among the treatment. The plant height (100.6cm) was recorded in the T_9 treatment, while the highest total grains panicle^{-1} (140), straw yield (8.317 t ha^{-1}), number non-effective tillers plant^{-1} (7.865), number sterile grains panicle^{-1} (24.33) were observed in T_{10} treatment. However, the highest number effective tillers plant^{-1} (18.67), number of total tillers plant^{-1} (14.20), and length of panicle (21.43 cm), number of fertile grains panicle^{-1} (117.4), 1000 grain weight (24.56g), grain yield (6.314 t ha^{-1}) and harvest index (52.51%) were opined in T_8. In contrary, the lowest plant height (75.85 cm), number of effective tillers hill^{-1} (12.67), number of non-effective tillers hill^{-1} (1.33), panicle length (16.48 cm), number of fertile grains panicle^{-1} (85.34), number of sterile grains panicle^{-1} (7), 1000 grain weight (19.74g), grain yield (2.194 t ha^{-1}), straw yield (4.08 t ha^{-1}) were recorded under control condition (T_1). The treatment T_8 performed better to all the treatments including T_9. Comparatively, better yield traits were obtained with the treatment T_8 (70% soil +10% foliar urea application) among all the treatments and the values were statistically similar to the treatment T_9 (100% urea soil application). To get the more confirmation and recommendation the experiments can be repeated in different agro ecological zone of Bangladesh.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world, grown in wide range of climatic zones. It is the staple food for nearly half of the world‘s population, most of who live in developing countries (Singh *et al*., 2012). Global population estimates have predicted the need for a 70% increase in rice production over the next 30 years (Lee *et al*., 2006). Due to the constant increase of the world’s population and adverse climatic conditions, the increase in the rate of rice production adequate to satisfy the increased demand for food should be approximately 1% per year (Sass *et al*., 2002). Almost 90 per cent of the paddy is grown and consumed in Asia (Khush and Brar, 2002). Millions of people in Asia subsist entirely on rice and over 90% of the world’s rice is grown and eaten in Asia (BBS, 2013). Rice is the staple food of about 160 million people of Bangladesh. This sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh. It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country (BBS, 2013). It is the most extensively cultivated cereal crop in Bangladesh.

Rice dominates the cropping pattern throughout the country as almost 80% of the cropped area is used for rice production, with annual production of 34.5 million metric tons in total acreage of 11.8 million ha. Boro rice is one of the major cereal food grains in Bangladesh, which is transplanted in winter season (December to February). Productivity of boro rice depends on several of climatic parameters, hydrological properties of soil, rice varieties, and major production inputs like irrigation and fertilizer management practices.

The climatic and edaphic conditions of Bangladesh are favorable for rice cultivation throughout the year. The average yield of rice in Bangladesh is quite low (2.35 t ha^{-1}) compared to that in other leading rice growing countries such as China (6.23 t ha^{-1}), Korea (6.59 t ha^{-1}), Japan (6.7 t ha^{-1}) and USA (7.04 t ha^{-1}) (FAO, 2004). On the other hand, rice production area is decreasing day by day due to high population pressure. Therefore, attempts should be taken to increase the yield per unit area through use of comparatively high yielding varieties along with proper and intensive fertilizer management and improved management practices. High yielding varieties of boro rice are greatly responsive and need adequate supply of fertilizer to achieve targeted production. It is an essential plant nutrient and involves in enzymatic reactions, protein synthesis and is a major component of amino and nucleic acids (FAO, 2004).For maximizing yield of rice, nitrogenous fertilizer is the kingpin in rice farming. Nitrogen can increase rice grain yield by increasing the total dry matter production, the number of panicles, and the panicle length of lowland rice (Wei *et al.*, 2011).

Nitrogen is the most important limiting nutrient in rice production and has heavy system losses when applied as inorganic sources in puddle field (Fillery, 1984). Many strategies have been developed to increase the efficiency of applied fertilizers through proper timing, deep placement, foliar application, modified forms of fertilizers, irrigation control etc. Among them foliar application of urea introduces a new dimension in the nitrogenous fertilization regime. In many cases aerial spray of nutrients is preferred and it gives quicker and better results than the soil application (Jamal *et al.*, 2006). Foliar application of urea has a significant effect on wheat yield (Moeini *et al.*, 2006). Recently foliar application of nutrients has become an important practice in the production of crops while application of fertilizers to the soil remains the basic method of feeding the majority of the crop plants (Manik *et al.*, 2016). The interest in foliar fertilizers arose due to the multiple advantages of foliar application methods such as rapid and efficient response to the plant needs, less product needed, and independence of soil conditions. It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase the crop yield (Kolota and Osinska, 2001). A high penetration rate is one of the pre-requisites for efficient foliar nutrition. Urea, due to its intrinsic characteristics such as small molecular size, non-ionic nature and high solubility, is usually taken up rapidly through the leaf cuticle. Urea can be supplied to plants through the foliage, facilitating optimal nitrogen management, which minimizes nitrogen losses to the environment. The report says that application of urea through foliar spray can reduce the requirement of urea fertilizer by 80% of soil application (Anonymous, 2009).

Foliar application of nitrogen was more effective than broadcast application alone in such situation the foliar application of plant nutrient is effective and economical for some crops (Mosluh *et al.*, 1978; Nafees *et al.*, 1993). Even several researchers have shown that foliar nitrogen application has a higher recovery rather than soil application (Shim *et al.*, 1972; Klein and Weinbaun, 1985; Weinbaum, 1988; Haq *et al.*, 2000). However, it is still believed that soil nitrogen application cannot be completely substituted by foliar application (Mengel, 2002) but can reduce the loss in yield due to non availability of nitrogen. In addition to fulfill the crop requirement, the combination of soil and foliar nitrogen application may be a more efficient use of N and reduces N losses (Fallahi and Simons, 1996; Khemira *et al.*, 1998). In many cases aerial spray of nutrients is preferred and gives quicker and better results than the soil application (Jamal *et al.*, 2006). So, it is necessary to improve the efficiency of applied nitrogenous fertilizer utilization by rice plant (Miah *et al.*, 1999; Rahman, 2010). Foliar spray of fertilizer does not only increase the crop yields but also reduce the quantities of fertilizer applied through soil (Akhand *et al.*, 2013). Foliar application can also reduce the lag time between application and uptake by the plant (BBS, 2014). Hence, every year a lots of urea fertilizer needs to import with an exchange of handsome amount of foreign currency. In a previous study, it was noted that soil application of urea in recommended dose gave higher but statistically similar yield to foliar application of 2% urea solution. However, economic analysis showed that foliar application alone is not replaceable by soil application. Therefore, the present study was selected with following objectives:

i) To study the effect of foliar application of urea solution on the yield and yield contributing characters of BRRI dhan28,

ii) To find out the suitable concentration and frequency of urea fertilizer to be sprayed in BRRI dhan28,

iii) To identify whether foliar application saves urea or not as compare to the conventional method.

CHAPTER II

REVIEW OF LITERATURE

The genetic potential of the rice varieties is mostly constant but the full expression of the genetic potential largely depends on cultural practices. A number of research works on the response of rice to different methods of fertilizers application have been carried out in the rice growing countries of the world including Bangladesh. A better understanding of the effects of different methods of urea application on rice in this country's soils would facilitate the development of suitable soil management practices for better production of this crop. In this chapter, an attempt has been made to review the research done in Bangladesh and elsewhere related to the effect of different methods of urea application.

Information on nutrient balance for a particular crop production system is very useful in developing nutrient management strategies for sustainable production. The continuous and unbalanced use of the chemical fertilizers under intensive cropping systems has been demand, production and import scenario of fertilizer requirement for boro rice production in Bangladesh considered as be the main cause for declining crop yield and environmental degradation. All essential elements must be present in optimum amounts and in forms usable by rice plants.

Among the various inputs that affect crop production, fertilizer is the single most important one that plays a crucial role in yield increase. Inorganic fertilizers today hold the key to success of the crop production system of Bangladesh agriculture, being responsible for about 50% of the total production (BARC, 2004).

Nitrogen is a primary element which plays a vital role in vegetative growth, development and yield of rice. BRRI (2001) reported that nitrogen has a positive influence on yield and yield components of rice. The important role of nitrogen fertilizers in increasing rice yield has been widely recognized particularly after the development of modern varieties.

Fertilizers are directly applied to the soil. Therefore, an amount of urea is lost by several means such as volatilization, leaching loss etc. before is completely taken by the rice plant. On the other hand, in urea spray the utilization of nitrogen by rice plant is rather quick and readily absorbed by the plant leaf surface opening.

2.1 Effect urea application in soil

Unfortunately, nitrogen use efficiency in the wetland rice culture is very low, rarely exceeding 30-40 % (Alam *et al*., 2000) and more than 50% of the applied nitrogen is lost through denitrification, volatilization, leaching and runoff (Khan *et al*., 2009), and ultimately affect on cash loss of farmers and sometimes causes environmental as well as ground water pollution (De Datta, 1981; IRRI, 1997). High price of urea fertilizer and its availability at the right time jeopardize rice production occasionally (BRRI, 2009).

It has been suggested that to improve nitrogen use efficiency the crop's demand for nitrogen, and its supply from indigenous and fertilizer sources, must be synchronized through proper timing, application rate, and placement of fertilizer (Sheehy *et al*., 2005).

The nitrogen application can be increasingly effected some traits such as dry matter, panicle length, panicle number per square meter which are correlated with grain yield (Bahmanyar and Ranjbar, 2007).

Rahman *et al*. (2005) concluded that nitrogen use efficiency is very low and the recovery of nitrogen in wetland rice seldom exceeds 40%. Many factors determine the fertilizer efficiency for rice crop during cultivation such as soil, cultivar, season, environment, planting time, water management, weed control, cropping pattern, source, form, rate and time of application and methods of application (De Datta, 2003).

Marginal increase in plant height with increase in nitrogen level through urea over other treatments might be due to more availability of nitrogen. Nitrogen is associated with increase in protoplasm, cell division and cell enlargement resulting in taller plants (Tisdale *et al*., 1985).

A field experiment was conducted by Ghosh (2007) during the 2002 and 2003 wet seasons in Cuttack, Orissa, India, to study the effect of stand density (high at 150 cm^2 hill at 15x10 cm^2 spacing; medium or normal 300 cm^2 hill at 15x20 cm^2 spacing; and low at 450 cm^2 hill at 15x30 cm^2 spacing) and nitrogen fertilizer rates (0, 40, 60 and 80 kg ha^{-1}) on the yield and nitrogen utilization of rice cv. *Sarala*. The result reported that nitrogen at 60 kg ha^{-1} combined with low density stand produced the highest grain yield (3.40 t ha^{-1}).

Ndaeyo *et al*. (2008) conducted an experiment in Nigeria with five rice varieties and found that higher nitrogen doses increased length of central panicle per plant.

The numbers of panicles are associated with the tiller production which is most important yield attributing character (Kaushal *et al*., 2011). Maximum panicle number under nitrogen fertilizer treatment was (12.38) observed for 300 kg ha^{-1} nitrogen and minimum of that was (10.66) obtained for 100 kg ha^{-1} nitrogen fertilizer.

Thakur (1991) reported that total spikelets $panicle^{-1}$ was the highest when 40%, 30% and 30% nitrogen was applied as basal, at maximum tiller and panicle initiation stages, respectively. Urea rates exerted significant influence on the production of number of grains $panicle^{-1}$ in BRRI dhan46. The highest number of grains $panicle^{-1}$ (161.85) was found when U4 (200 kg ha^{-1}) was applied in the crop field and it was identical to U1 (140 kg ha^{-1}). Application of U2 (160 kg ha^{-1}) produced the second highest number (157.40) of grains panicle^{-1} and it was followed by U3 (180 kg ha^{-1}) and U5 (220 kg ha^{-1}). The lowest number of grains panicle^{-1} (138.71) was recorded from application of U5 (220 kg ha^{-1}).

Moinul *et al*. (2008) reported that different growth stages (50, 70 and 90 DAT) maximum number of tillers hill^{-1} was found from Tia (16.23, 21.34 and 21.45, respectively) and the lowest number of total tiller was recorded in BRRI hybrid dhan2 (11.66, 16 and 15.76, respectively).The other findings by Bisne *et al*. (2011) and Devaraju *et al*. (2013) were similar with the present findings.

Stefan and Stefan (1990) conducted an experiment during 1987-1989.They used 0-120kg nitrogen ha^{-1} applied to soil and 0-90 kg nitrogen applied to leaves of rice at 4-5 leaves, 7-8 leaves or shoot elongation stages. Grain yields ranged from 3.52 and 3.08 ton ha^{-1} without 7.77 ton and 6.60 ton with 60 kg nitrogen applied to soil. Application of 60 kg nitrogen as urea at 4-5 and 7-8 leaf stages increased yield and quality of rice.

Maximum panicle dry matter (954.93) under nitrogen fertilizer treatment was observed for 300 kg ha^{-1} nitrogen and minimum of that was (892.94) obtained for 100 kg ha^{-1} nitrogen fertilizer. The heaviest panicles were recorded when nitrogen was applied at the rate of 200 kg ha^{-1} nitrogen fertilizer. This trend might be due to the role of nitrogen in crop maturation, flowering and fruiting including seed formation (Metwally *et al.*, 2011).

Manzoor *et al*. (2006) was conducted a study during kharif season of three successive years from 2001 to 2003 at Rice Research Institute, Lahore, Pakistan. Nine nitrogen levels (0, 50, 75, 100, 125, 150, 175, 200 and 225 kg ha^{-1}) were studied to see their effect on paddy yield. According to the results plant height, number of productive tillers per hill, panicle length, number of grains per panicle, 1000 grain weight and paddy yield showed increasing trend from up to 175 kg nitrogen per hectare. The yield parameters including paddy yield, number of grains per panicle and 1000 grain weight started declining at 200 kg nitrogen per hectare level and above. The maximum paddy yield (5.34 t ha^{-1}) was obtained from 175 kg nitrogen application which also produced higher number of grains per panicle (142.27 cm) along with maximum 1000 grain weight (24.96 g). The plant height (145.56 cm), productive tillers per hill (19.67) and panicle length (36.62 cm) were the maximum at 225 kg nitrogen level. Similar results were also found by Nerson *et al*. (1980) who observed that the increasing nitrogen supply increased the number of filled spikelets due to promotion of the rate of spikelets initiation.

Rahman *et al*. (2001) conducted an experiment where the results showed significantly influenced growth and yield components, and the maximum grains $panicle^{-1}$ was found at 80 kg ha^{-1} nitrogen.

Geethadevi *et al*. (2000) found that 120 kg ha^{-1} nitrogen in the form of urea 50% of nitrogen was applied as basal rate to all treatments while the remaining 50% was applied in four splits resulted in higher number of tillers. Number of total tillers $hill^{-1}$ was significantly influenced by the different rates of urea application. The highest number of tillers $hill^{-1}$ (15.19) obtained from U4 (200 kg ha^{-1}) and plants receiving 220 kg ha^{-1} (U4) produced the lowest number of tillers $hill^{-1}$ (11.49). This might be the lodging effect of the hills resulting from excess uptake of nitrogen for higher dose.

Sarkar *et al.* (2001) reported that application of nitrogen increased straw yield significantly up to 120 kg ha^{-1} nitrogen. Singh *et al.* (2000) claimed each incremental dose of nitrogen gave significantly higher straw yield.

More dry matter accumulation at 150% recommended dose of nitrogen might be due to increased nitrogen availability which is responsible for profound tiller and higher growth rate. Similar results were also reported by Stalin *et al*. (1999); Rao *et al*. (2004); Dwivedi *et al*. (2006) and Prasad Rao *et al*. (2011).

Masud (2006) reported that application of nitrogen exerted positive effect on all crop characteristics. The rice genotypes differ significantly in yield contributing characters and grain yield.

Mandal and Swamy (2003) found that application of nitrogen (120 kg ha^{-1}) as urea in equal splits during transplanting, tiller panicle initiation and flowering resulted in the highest number of panicles, number of filled grains $panicle^{-1}$, 1000 grain weight, straw yield and harvest index.

Methods of urea application did not influence the plant height significantly in aman rice *cv*. BRRI dhan46. However, numerically the taller plants (114.05 cm) were found from split application of urea while the plant height reaches maximum (113.99 cm) through soil application.

Akanda *et al*. (1986) found that tallest plants were produced when nitrogen 80 kg ha^{-1} was applied in three splits (20 kg at basal, 40 kg at active tiller and 20 at maximum tiller). The plant height of BRRI dhan46 was significantly affected by the rates of urea fertilizer. Plant height ranged from 108.17 to 116.21 cm. The tallest plant (116.21 cm) was found with U4 (180 kg ha^{-1}) while shortest one (108.17 cm) was found when U5

(220 kg ha^{-1}). The shortest plant at U5 might be the effect of excess uptake of nitrogen from highest dose of nitrogen application resulting lodging of plants which resulted stunted growth of the plant.

Panicle length was significantly influenced by nitrogen treatment (Bahmanyar and Soodaei Mashaee, 2010). Asif *et al*. (2000) reported that greater panicle length in nitrogen ($^{1}/_{3}$ at transplanting + $^{1}/_{3}$ at early tillering stage + $^{1}/_{3}$ at panicle initiation) might again be due to sufficient availability of nitrogen at panicle emergence stage.

Faraji and Mirlohi (1998) reported that plant height increased with an increase in the rate of nitrogen fertilizer application nitrogen 60, 90, 120 and 150 kg ha^{-1} were given before transplanting or in 2 or 3 splits while grain yield and panicle number increased with up to nitrogen 120 kg ha^{-1} but decreased at nitrogen 150 kg ha^{-1}. Plant height of BRRI dhan46 was not significantly influenced by the interaction of methods and rates of urea application. Numerically the highest plant height (117.48 cm) was found from M1U1 (split of urea 140 kg ha^{-1}) and the lowest (108.06 cm) from M2U5 (spray of urea 220 kg ha^{-1}). The shortest plant in M2U5 might be the effect of excess amount of urea in the soil due to highest dose and simultaneous spray causes failures of equal nitrogen uptake by the plant for proper growth which results stunted growth of the plant.

Ehsanullah *et al*. (2001) reported that nitrogen as split application at different growth stages significantly affected grain yield. Grain yield of BRRI dhan46 was significantly affected by the rates of urea fertilizer. The highest grain yield (5.20 t ha^{-1}) was obtained with the rate of U4 (200 kg ha^{-1}) but it was identically followed by U2 (160 kg ha^{-1}) and U1 (140 kg ha^{-1}). The highest yield obtained by the treatments might be due to the contribution of effective tillers hill^{-1} and number of grains panicle^{-1}. The results revealed that U1 (140 kg ha^{-1}), U2 (160 kg ha^{-1}), and U4 (220 kg ha^{-1}) produced the identical but highest yield. Therefore, 140 kg ha^{-1} urea may be suggested to grow BRRI dhan46. The lowest yield (3.13 t ha^{-1}) was found from U5 (220 kg ha^{-1}).

Singaravel *et al.* (2007) conducted an experiment to study the effects of recommended NPK rates (120:38:38) with or without kiecite (a foliar micronutrient mixture containing 1.0% Fe, 0.5% Zn, 0.35% Cu and 0.05% B at 0.50, 1.0, 1.5 or 2.0%) on the performance of rice studied in Annamalia, Tamil Nadu, India from July to October 2003. They reported that NPK + 1.0% kiecite significantly enhanced the growth and yield of rice.

Hossian *et al.* (2007) observed that nitrogen rates have significant effect on yield and yield attributes of transplanted aman rice. The highest grain yield was obtained from the application of 75% of the recommended dose (150 kg urea i.e. nitrogen 69 kg ha^{-1}) of nitrogen and the lowest from the control (0 kg ha^{-1}). Significant variation in grain yield (t ha^{-1}) was observed in BRRI dhan46 due to the interaction of different rates and methods of urea. The highest grain yield (5.42 t ha^{-1}) was obtained from the combination of M1U4 (Split of urea 200 kg ha^{-1}) and the lowest grain yield (2.88 t ha^{-1}) was obtained from the interaction of M2U5 (Spray of urea 220 kg ha^{-1}).

Poshtmasari *et al.* (2007) from the Rice Research Institute of Iran reported that nitrogen fertilizer rates and split application had significant effect on dry matter remobilization in shoot, stem and leave (except flag leaf). This amount was obtained at the 100 kg ha^{-1} nitrogen fertilizer and the first split application treatment. The highest rate of dry matter remobilization in leaves (except flag leaf) was obtained in 200 kg ha^{-1} nitrogen fertilizer level. Also, flag leaf had the highest dry matter remobilization, although it was not affected by nitrogen fertilizer rates and split application.

Idris and Matin (1990) noticed that the maximum tillers hill^{-1} was reduced with 140 kg ha^{-1} nitrogen which was statistically similar to these with nitrogen 60, 80, 100 and 120 kg ha^{-1}. The minimum tillers hill^{-1} was obtained from the control treatment (0 kg ha^{-1}).

BRRI (2000) reported that nitrogen has a positive influence on yield and yield components of rice. The important role of nitrogen fertilizers in increasing rice yield has been widely recognized particularly after the development of modern varieties. The nitrogen content of Bangladesh soil is low due to warm climate accompanied by extensive cultivation. The efficiency of applied nitrogen use by the rice plant is also low.

The number of productive tillers m^{-2}, total number of grains panicle^{-1}, number of filled grains panicle^{-1}, were significantly influenced by nitrogen levels only where in application of 150% recommended dose of nitrogen exerted favorable influence and improved all the yield attributes. Increase in level of nitrogen application will increase the number of filled grains panicle^{-1} as reported by (Channabasavanna *et al*., 2001).

2.2 Effect of urea in foliar application

Chemical fertilizer, if applied in excess amount, has a harmful effect on soil physical, chemical and biological properties. It inhibits growth and development of soil microorganism. As foliar application reduces the use of excess chemical fertilizer, it will be beneficial for soil environment. Recently foliar application of nutrients has become an important practice in the production of crops while application of fertilizers to the soil remains the basic method of feeding the majority of the crop plants. Moreover, application of urea through foliar spray can reduce the requirement of urea fertilizer by 80% of soil application (Annonymous, 2009).

Pot experiments were conducted by Andreevska *et al*. (2003) to determine the effect of nitrogen fertilizers on the dry matter yield and the total nitrogen content in the roots, stems, leaves and panicles of rice. The complex fertilizer was applied as a basic treatment, while the nitrogen fertilizer was applied as a double foliar split application at the start of the heading stage. The result reported that the method and the time of nitrogen application showed a significant positive effect on the yield increase of row and dry matter of roots and aboveground parts and on their total nitrogen content.

Moeini *et al*. (2006) conducted a 3-year trial from 1999 to 2001 in Karaj, Iran. Treatments included 9 levels of urea application in two methods (foliar application and top dressing). The results indicated that foliar application of urea had a significant effect on yield. Rates of urea application significantly influenced the straw yield of BRRI dhan46.

Borjian and Emam (2001) conducted a field experiment in Shiraz, Iran, during 1998-99, the effect of rate and time of foliar urea application on protein content and quality in two cultivars of winter wheat Falai and Marvdashf was studied. A split plot arrangement of treatments in a randomized complete block design was used with cultivars as the main plots and factorial levels of five urea foliar application rates nitrogen (0, 8, 16, 24 and 32 kg ha^{-1}) and three stages of application (booting, anthesis and early milk), as subplots. The results showed that each 8 kg ha^{-1} increment in nitrogen applied as urea was associated with a 0.6% increase in grain protein in both cultivars. Both grain yield and protein percentage increased, resulting in higher protein yield.

Field experiments were conducted by Ravi *et al*. (2007) at Annamalia University Experimental Farm (Tamil Nadu, India) during Navarai and Kuruvai season to study the effect of foliar spray of phytohormones and nutrients on the yield and nutrient uptake of transplanted rice cv. ADT 36. The results revealed that foliar application of miraculan 1000 ppm recorded an added beneficial effect over other treatments. Different methods of urea fertilizer application exhibited significant difference in producing number of total tillers hill^{-1} in BRRI dhan46. The higher number of total tillers hill^{-1} (14) was obtained when urea fertilizer was applied in 4 equal splits. On the other hand, the lower number of total tillers hill^{-1} (13.15) was obtained from spray of urea fertilizer.

Chopra and Chopra (2000) reported that application of either 80 or 120 kg ha^{-1} nitrogen improved the entire yield attributes compared to control. Results of grain yield revealed that application of 2% urea solution is not enough to produce good yield (3.80 t ha^{-1}), while with ½ soil application + 2% urea solution, the performance was better (4.97 t ha^{-1}).

Mosluh *et al*. (1978) showed that foliar feeding of urea in combination with soil application to wheat crop gave significant increase in the grain yields. In traditional method, one-third urea is applied 15 days after transplantation (DAT) and rest of the urea is applied in two equal splits in 25-35 DAT and 45-55 DAT, respectively, depending on the life duration of the respective variety (BRRI, 2016).

Parvin *et al*. (2013) conducted an experiment to investigate the effect of foliar application of urea on BRRI dhan29 and found that yield and yield contributing characters (i.e. highest number of effective tillers hill^{-1}). The grain yield of BRRI dhan29 has been significantly increased due to foliar application of nitrogen fertilizers. There were numerical variations in grain yield among the treatments. The highest grain yield was recorded for T5 (50% prilled urea + 5 foliar spray 0.5% solution ha^{-1} i.e. 5.5 kg spray^{-1} nitrogen + 5 t ha^{-1} cow dung) which was identical to T6 (70% prilled urea + 3 foliar spray 0.5% nitrogen solution ha^{-1} i.e. nitrogen 5.5 kg spray^{-1} + 5 t ha^{-1} cow dung) and T7 (50% prilled urea + 3 foliar spray 1.0% nitrogen solution ha^{-1} i.e. nitrogen 11kg spray^{-1} + 5 t ha^{-1} cow dung). These results indicate positive effects of foliar application of nitrogen fertilizers on rice yield. The increase in rice yield is due to the direct supply of nitrogen from foliar spray throughout the growing period of rice and due to minimum loss of nitrogen as because of foliar application.

These findings are well corroborated with Rahman (2010) who observed increased rice yield due to foliar application of nitrogen. Another findings Shaila (2009) showed negative effect of foliar application where soil application is not replaceable by foliar application.

Duraisami *et al*. (2002) had conducted field experiments during the winter of 1991-95 and 1996-97 to determine the suitable nutrient management for rice. The treatments comprised soil application of 100% recommended NPK rate (T1), T1+ 20% additional nitrogen (T2), 50% recommended nitrogen + 100% recommended P and K rates + 2.5% urea foliar spray at the active tiller and panicle initiation stages (T3), 100% P and K rates +2.5% urea foliar spray at active tiller panicle initiation, mid-heading, first flowering and 50% flowering stages (T4), T1+ 2 kg phosphor bacterium per ha (T5), 25kg zinc phosphate (T6), T1+ 2% urea foliar spray application at active tiller and panicle initiation stages (T7) and T1+ 1% zinc sulphate spraying at active tiller and panicle initiation stages (T8). The treatment T2 resulted in the tallest plant (101.9 cm) and highest number of productive tillers (10), grain yield (6713 kg ha^{-1}) and straw yield (918 kg ha^{-1}), whereas T3, T4 and T7 gave the highest chaff per panicle (12.4) harvest index (43.64%) and number of grains per panicle, respectively.

Alam *et al*. (2006) observed that liquid fertilization with magic growth along with 75% of the recommended nitrogen fertilizer increased 10.5% grain yield with a saving of 25% of the recommended nitrogen fertilizer compared to recommended practice.

Shafiee *et al*. (2007) conducted an experiment using liquid fertilizer SBAJATM (formerly known as BIPOMIXTM) and found the highest yield of grains (9.66 tons ha^{-1}) compared with (7.49 tons ha^{-1}) in the control plots.

Islam *et al*. (1996) observed that grain yield influenced significantly due to application of different rates of nutrients and 60-19-36 kg ha^{-1} NPK maximized the yield of treatment aman rice varieties. The data revealed significant increase in grain yield with foliar application of urea. The highest grain yield (3.03 t ha^{-1}) was produced by 2% urea application. The yield was, however, statistically at par with that of 1% urea application (3.01 t ha^{-1}). On the contrary, the lowest grain yield (2.85 t ha^{-1}) was produced by control treatment. This increase might be mainly due to the additional availability of nitrogen till later growth stages of wheat. The findings are in agreement with those of Alston (1979), Strong (1982) and Gooding and Devies (1992) who reported increased grain yield for foliar application of nitrogen.

Rahman *et al*. (2014) that the data on number of effective tillers m^{-2} revealed significant increase with foliar application of urea. The maximum number of tillers (25) was recorded in the treatment of foliar spray of 2% urea (FN77) which was statistically at par with the that of 1% urea (FN38) and the minimum tillers (218) was recorded from the N0 (control) treatment. These results are in agreement with those of Alston (1979) who reported better performance of wheat with foliar application of nitrogen. Hagras (1985) also reported increased number of effective tillers per square meter of wheat with increasing nitrogen rate.

Application of nitrogenous fertilizer to the leaves is more efficient because in this way many possible pathways for nitrogen loss associated with the application of nitrogen to the soil are avoided (Mosali *et al*., 2006).

Study of the data revealed that foliar application of urea resulted in a significant increase in thousand grain weight. The highest thousand-grain weight (46.32g) was found from 1% urea spray which was statistically identical with that of 2% urea spray (46.17g). The lowest thousand-grain weight (43.10g) was noticed from the control (N0) treatment. Foliar application of urea at the later growth stages of the crop might have increased the availability of nitrogen to the crop which favored enhanced accumulation of photosynthate in the grains. The results are in line with Abedin (1995) who reported significant increase in thousand-grain weight with application of nitrogen.

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Similar results were also found by Nerson *et al*. (1980) who observed that the increasing nitrogen supply increased the number of filled spikelets due to promotion of the rate of spikelets initiation.

The findings are in agreement with those of Gooding and Devies (1992) who found better performance of wheat crop for foliar application of nitrogen. Significant increased in grain number per spike with increasing nitrogen rates up to certain limit was also reported by (Wali *et al*., 1987; and Ellen 1990).

Chander and Pandy (1996) stated that a significant increase in grains panicle^{-1}, tillers m^{-2} and grain yields was obtained from application of nitrogen 120 kg ha^{-1} compared to nitrogen 60 kg ha^{-1}.

Chopra and Chopra (2004) reported that nitrogen had significant effects on yield attributes such as plant height, panicle length and thousand grain weight with increasing levels of nitrogen up to 120 kg ha^{-1}.

Khan *et al*. (2009); Gul *et al*. (2011) and Saeed *et al*. (2012) also supported the same theory that foliar application of urea significantly increased plant height, spike length, number of grains spike^{-1} 1000 grain weight, grain yield and nitrogen uptake by crop when sprayed at tiller, stem elongation and booting stage. The 1000 grain weight indicated the vigor of grain as an important yield contributing factor.

Similarly, in case of uptake, the ½ soil + 2 sprays of 2% urea gave maximum concentration of nitrogen and uptake. The nitrogen content in treatment of 1% urea spray, 3% urea spray and ½ portion urea at sowing + 2% foliar spray were statistically similar. Tea *et al*. (2007) reported that foliar nitrogen fertilization on wheat at optimum timings increased the remobilization of nitrogen to grain and increased grain protein content. The results also are in agreement with (Mosluh *et al*., 1978 and Swenson *et al*., 2009).

Significant variation in grain yield (t ha^{-1}) was observed BRRI dhan46 due to different fertilization methods of urea application. The highest grain yield (4.66 t ha^{-1}) was obtained from split application of urea fertilizer whereas same application of urea as spray method produces grain 4.34 tons ha^{-1}. The increased yield with split method of urea was contributed by higher number of effective tillers hill^{-1}, higher number of grains panicle^{-1} and individual grain weight.

Islam *et al*. (1996) reported that number of effective tillers $hill^{-1}$ increased with top dressing of nitrogen. Different rates of urea application exhibited significant difference in producing the number of effective tillers $hill^{-1}$ in BRRI dhan46. The highest number of effective tillers $hill^{-1}$ (12.16) was found with U4 (200 kg ha^{-1}) as U1 (140 kg ha^{-1}) and U2 (160 kg ha^{-1}) statistically followed the same trend as U4 in terms of total number of effective tillers $hill^{-1}$. The lowest number of effective tillers $hill^{-1}$ (8.28) was obtained from U5 (220 kg ha^{-1}).

BRRI (1992) stated that productive tillers $hill^{-1}$ was significantly affected by the level of nitrogen. The highest number of productive tillers $hill^{-1}$ was obtained from the highest level of nitrogen (120 kg ha^{-1}). The effect of interaction between rates and methods of urea application was not significantly affected the number of effective tillers $hill^{-1}$. Methods of urea fertilizer application significantly influenced the straw yield of BRRI dhan46. The highest straw yield (6.24 t ha^{-1}) was recorded when urea is applied in split method. Spray method produces straw 6.12 tons ha^{-1} which was significantly lower than split method of urea application.

CHAPTER III

MATERIALS AND METHODS

The materials and methods were used for conducting the experiment has been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure. The production method followed is described below along with the experimental aspects of the present study.

3.1 Description of the experimental site

3.1.1 Location experimental site

The experiment was carried out at the Agronomy Research Field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur .The geographical location of the site is between 25º13' latitude and 88º23' longitude, and about 37.5 m above the sea level during December 2017 to March 2018. The experimental plot was in a medium high land belonging to the Old Himalayan Piedmont Plain area (AEZ-1).

3.1.2 Soil

The experimental plot was in a medium high land belonging to the Old Himalayan Piedmont Plain area (AEZ-1) comprising sandy loam texture with pH 5.1. The site is characterized by tropical climate, heavy rainfall from July to August and scanty rainfall the rest period of the year. 80 to 90% is received between June and September. The remaining 10 to 20% rainfall is received during wheat growing season November to April (IWFM, 2014). The experimental field is a medium high land having sandy loam soil with pH 5.35. The initial soil (0-15 cm depth) test revealed that the soil contained

0.10% total nitrogen, 1.06% organic matter, 24.00 µg g^{-1} available phosphorus, 0.26 meq/100g available potassium, 3.2 µg g^{-1} available sulphur and 0.27 µg g^{-1} boron. The characteristics of the soil were tested at the Soil Resource Development Institute (SRDI), Dinajpur (Appendix II).

3.1.3 Climate

The experimental site is under the subtropical climate where the boro season (November, 2017 to April, 2018) starts with low temperature and plenty of sunshine. When the season proceeds towards the kharif season (April to September 2018) the atmospheric temperature increases. The mean maximum temperature rises in the month of April, whereas in winter the mean. Usually there is high temperature, high humidity and heavy rainfall (above temperature comes down to the lowest in January. Usually there is high temperature, high humidity and heavy rainfall (above 80% of the total rainfall) with occasional gusty winds in the kharif season and scanty rainfall associated with moderately low temperature during October to March (rabi season). Weather data regarding rainfall, relative humidity and sunshine hours prevailing at the site during the study period are presented in (Appendix III).

3.2 Experimental treatment and design

3.2.1 Treatments

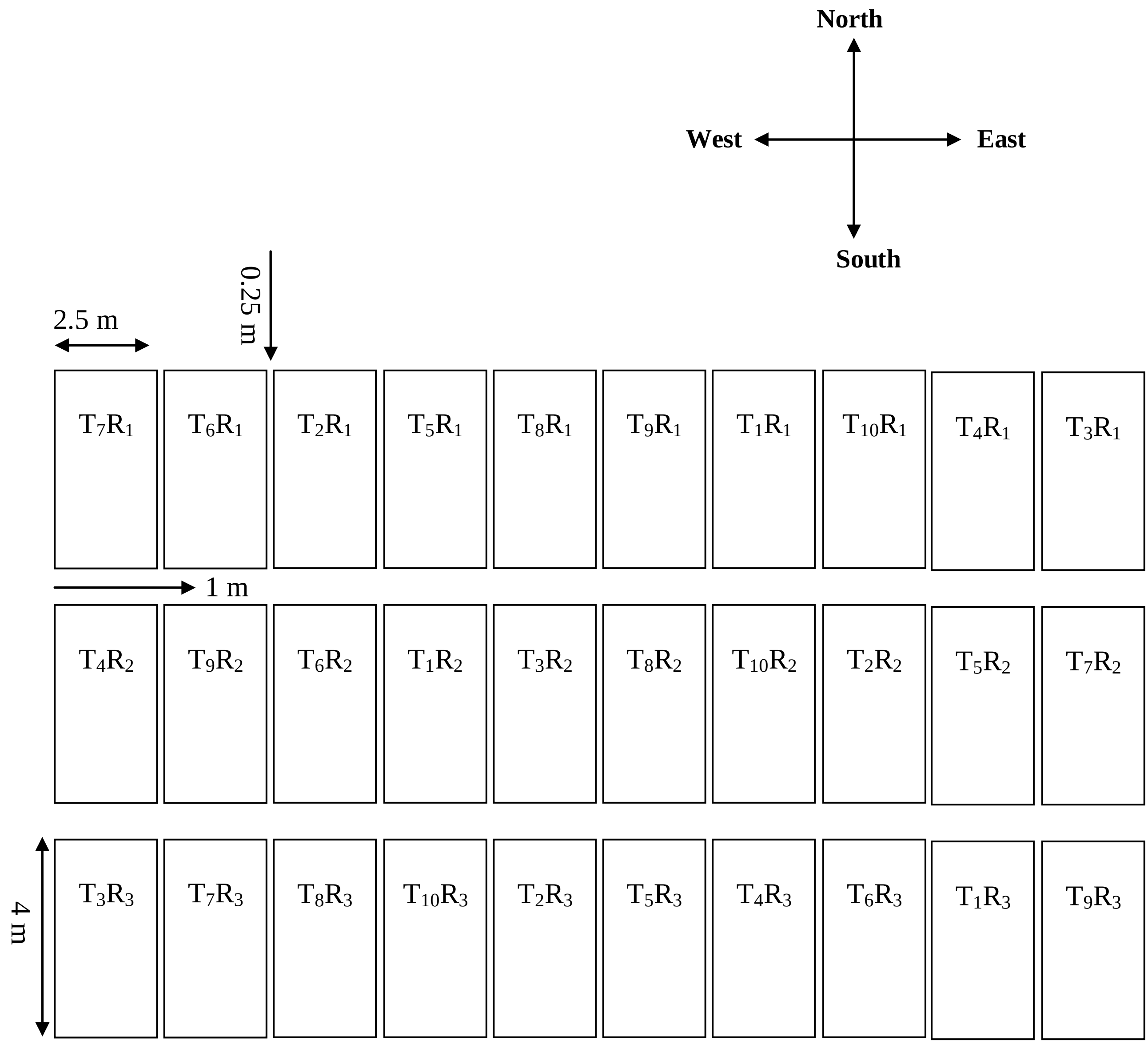
The experiment included the following treatments:

Treatment material:

T_1 N_0 urea	Control (no urea used) other fertilizers applied during final land preparation.
T_2 N_{50}% SA+$_{10}$% FA	After 10 DAT 20% urea+25 DAT 30% urea applied in soil. After 40 DAT 5% urea as foliar application (31.25g urea+10g MoP+1g thiovit+0.5g chelated zinc+.0.25g liberal boron. After 50 DAT same FA.
T_3N_{50}% SA+$_{15}$% FA	After 10 DAT 20% urea+25 DAT 30% urea applied in soil. After 40 DAT 5% urea as foliar application (31.25g urea+10g MoP+1g thiovit+0.5g chelated zinc+0.25g liberal boron. After 50 DAT and 60 DAT same FA.
T_4N_{50}% SA+$_{20}$% FA	After 10 DAT 20% urea+25 DAT 30% urea applied in soil. After 40 DAT 6.66% urea as foliar application (41.62g urea+10g MoP+1g thiovit+0.5g chelated zinc+.0.25g liberal boron. After 50 DAT and 60 DAT same FA.
T_5N_{60}% SA+$_{10}$% FA	After 10 DAT 25% urea+25 DAT 35% urea applied in soil. After 40 DAT 5% urea as foliar application (31.25g urea+10g MoP+1g thiovit+0.5g chelated zinc+0.25g liberal boron. After 50 DAT same FA.
T_6N_{60}% FA+$_{15}$% FA	After 10 DAT 25% urea+25 DAT 35% urea applied in soil. After 40 DAT 5% urea as foliar application (31.25g urea+10g MoP+1g thiovit+0.5g chelated zinc+0.25g liberal boron. After 50 DAT and 60 DAT same FA.
T_7N_{60}%SA+$_{20}$%FA	After 10 DAT 20% urea+25 DAT 30% urea applied in soil. After 40 DAT 6.66% urea as foliar application (41.62g urea+10g MoP+1g thiovit+0.5g chelated zinc +0.25g liberal boron. After 50 DAT and 60 DAT same FA.
T_8N_{70}% SA+$_{10}$% FA	After 10 DAT 30% urea+25 DAT 40% urea applied in soil. After 40 DAT 5% urea as foliar application (31.25g urea+10g MoP+1g thiovit+0.5g chelated zinc+.0.25g liberal boron. After 50 DAT same FA
T_9N_{100}% SA	Traditional method (33.33% final land preparation, 33.33% at 25 DAT and 33.33% at 40 DAT)
$T_{10}N_{100}$% SA+$_{10}$% FA	Traditional method (33.33% final land preparation 25 DAT 33.33% and 40 DAT 33.33% urea applied. After 40 and 60 DAT 10% urea as foliar application (31.25g urea+10g MoP+1g thiovit+0.5g chelated zinc+.0.25g liberal boron.

3.3 Experimental design

The experiment was laid out in a randomized complete block design. There were 10 treatment combinations, each treatment replicated three times. The treatments were randomly distributed to the plots within a block. Thus, the number of plots was 3×10= 30. The unit plot size was 4.0 m x 2.5 m =10 m^2.



3.4 Varietal description

BRRI dhan28 was used as the test variety in the study. It is one of the important boro rice cultivar developed by the Bangladesh Rice Research Institute (BRRI) from the cross between BR6 and Purbaci and was released in 1994 as boro rice. It attained the height of 90 cm and grain yield may be 5-6 t ha^{-1}. It is well adapted variety in our climatic conditions and its field performance excellent after long time cultivation.

3.5 Production technology

3.5.1 Seed collection

Healthy and vigorous seeds of BRRI dhan28 were collected from Bangladesh Agriculture Development Corporation (BADC), Dinajpur.

3.5.2 Seed sprouting

Healthy seeds were selected by specific gravity method by immersing them in bucket for 24 hours. Then the seeds were taken out of water and kept thickly in a gunny bag. The seeds started sprouting after 48 hours and were sown after 72 hours in the nursery bed.

3.5.3 Preparation of nursery bed and seed sowing

Seedling nursery was prepared by puddling the soil. Weeds and stubble were removed and the land was leveled properly. Sprouted seeds were sown in broadcast method in the wet nursery bed on 14 December 2017. Proper care was taken to raise good seedlings in the seedbed. Weeds were removed and irrigation was given in the seed bed as and when necessary. A nylone net was surrounded around seedling bed for protected the seedling.

3.5.4 Preparation of experimental land for transplanting

The experimental land was first opened with a power tiller on 1st January 2018. The land was submerged with enough water and thoroughly prepared with the help of country plough and ladder. This condition was kept for two days with sufficient water. Weeds and stubble were removed from the field. The bunds around individual plots were made for proper water management between the plots. The individual plots of each block were prepared thoroughly by spading and then leveled just before the specified date of transplanting on 23 January 2018.

3.5.5 Fertilizer application

The field was fertilized with triple super phosphate, muriate of potash, gypsum and zinc sulphate@ 120, 75, 60 and 10 kg ha^{-1}, respectively. The whole amount of triple super phosphate, muriate of potash, gypsum, zinc sulphate and 500g dry cow dung was applied at final land preparation. Recommended dose of urea were applied in soil at 10 DAT and 25 DAT on 3 February and 28 February 2018. Foliar application urea were applied as recommended at 40, 50, 60 DAT on 15 March 26 March 5 April 2018, respectively.

3.5.6 Uprooting of seedlings and transplanting

Seedlings of 40 days old were uprooted carefully from the nursery bed and transplanted in the individual plot on 23 January 2018 at the rate of 2-3 seedlings $hill^{-1}$ with a spacing of 20 cm x 20 cm.

3.5.7 Intercultural operations

Intensive care was taken during the growing period for proper growth and development of the rice crop. The following intercultural operations were done.

3.5.7.1 Gap filling

Seedlings in some hills died off and those were replaced by gap filling after seven days of transplanting with seedlings from the same source.

3.5.7.2 Weeding

Three hand weeding were done during the whole growth period. The first weeding was given at 15 days after transplanting (DAT) on 30 January 2018 the second weeding at 30 (DAT), on 14 February 2018, and the third weeding at 45 (DAT) on 2 March 2018.

3.5.7.3 Irrigation and drainage

The land was with water and land dry 25 days after transplanting. Excess water was drained out from the plots before 15 days of harvest to enhance maturity of the crop.

3.5.7.4 Plant protection measures

The crop was found to be infested with brown plant hopper (BPH) and were successfully controlled by spraying Sumithion 50EC 1.5 litres ha^{-1} twice for the entire growing period at 35 and 55 DAT. Virtako 40 WG was applied for controlling rice yellow stem borer at 40 DAT and before butting stage of rice at 30g per acre Super Mac (Green Bangle Agrovet Ltd.) was applied two times at 60 DAT and after panicle initiation stage at 10g per 33 decimals.

3.5.8 Sampling, harvesting and processing

The crop was harvested at full maturity. The date of harvesting was confirmed when 90% of the grain became golden yellow in color. Harvesting was done on 24 April 2018. Five hills (excluding border hills) were selected randomly from each individual plot and uprooted before harvesting for recording data. After sampling the whole plot was harvested. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. Each area of 10 m^2 from the farmer's field from three different locations chosen randomly was harvested to record the grain and straw yield from the farmer's cultivation method. The harvested crops were threshed manually. The grains were cleaned and dried to a moisture content of 12%. Straws were sun dried properly. Final grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.6 Data Collection

3.6.1 Parameters

Data on yield and yield contributing characters were recorded from five randomly selected sample plants from each plot on the following parameters:

1. Plant height (cm)
2. Relative water content (%)
3. Total tillers $hill^{-1}$
4. Dry matter (g)
5. Number of effective tillers $hill^{-1}$
6. Number of non-effective tillers $hill^{-1}$
7. Panicle length (cm)
8. Number of grains $panicle^{-1}$
9. Number of fertile grain $panicle^{-1}$
10. Number of sterile $panicle^{-1}$
11. Thousand grains weight (g)
12. Grain yield (t ha^{-1})
13. Straw yield (t ha^{-1})
14. Biological yield (t ha^{-1})
15. Harvest index (%)

3.6.2 Procedure of data collection

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

i) Plant height (cm)

Average plant height was recorded from randomly selected plants in each plot. The plant height was measured from the base to the tip of the uppermost spikelet of the plant and expressed in centimeter (cm).

ii) Relative water content (%)

It is probably the most appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit.

RWC (%) = [(W-DW) / (TW-DW)] x 100**,**

Where, W = Sample fresh weight

TW = Sample turgid weight

DW = Sample dry weight.

iii) Total number tillers hill^{-1}

To get total tillers hill^{-1}, all the tillers were counted from each sample and then average of sample plants were taken. It included both effective and non-effective tillers.

iv) Number of effective tillers hill^{-1}

To get the effective tillers hill^{-1}, only the ear bearing tillers were counted from each sample and then the average of samples were taken.

v) Dry matter (g)

The difference in the initial sample weight and the final dry weight of the sample represents the amount of water in the sample. The DM is 100 less the proportion of water. A simple formula for calculation of DM is as follows:

DM (%) = 100 - [(original weight - dry weight) ÷ original weight] x 100, or dry weight × 100/fresh weight.

vi) Number of non-effective tillers hill^{-1}

To get the non-effective tillers hill^{-1}, i.e. those with no panicles, were counted from each sample and then the average of samples were taken.

vii) Panicle length (cm)

Panicle length was recorded from each panicle and then the average was expressed in centimeter (cm) from the first node to the tip of the panicle.

viii) Number of grains panicle^{-1}

Number of grains panicle^{-1} was counted and then the average of samples was taken.

ix) Number of fertile grain panicle^{-1}

From the above mentioned samples the sterile spikelets panicle^{-1} were counted and the average of samples were taken.

x) Number of sterile grain panicle^{-1}

From the above mentioned samples the fertile grain panicle^{-1} were counted and the average of samples were taken.

xi) Thousand grains weight (g)

One thousand grains were randomly taken from each plot and it was dried to 12% moisture content. Then the weight was by an electrical balance and expressed in gram (g).

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

Grain obtained from each unit plot was sun dried and weighed carefully. Weight of sun dried grains of each plot was taken and converted to finally in t ha^{-1}.

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

Weight of sun dried straw obtained from each unit plot including the straw of sample plants were taken to record the straw yield per plot and it was finally converted to t ha^{-1}.

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

Grain yield and straw yield together are regarded as biological yield. The biological yield was calculated with the following formula: Biological yield = grain yield + straw yield.

xv) Harvest index (%)

Harvest index was calculated on the basis of grain and straw weights using the following formula. It is express as %HI=grain yield ×100/biological yield.

3.7 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Rage Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents results and follow-up discussion on the effect of soil and foliar application of urea on the yield contributing characters, yield of BRRI dhan28. The data have been shown in various features.

4.1 Plant height (cm)

Plant height of BRRI dhan28 was significantly influenced by the soil and foliar application of urea.

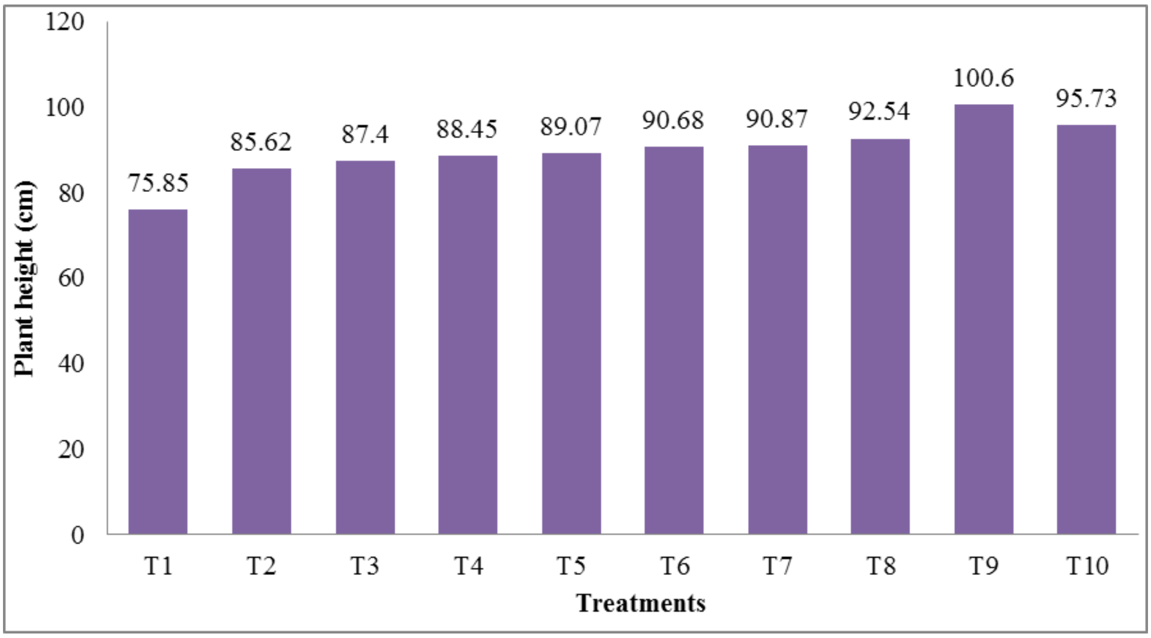


Fig. 1 Effect of soil and foliar application of urea on the plant height (cm) of BRRI dhan28

It ranged from 75.85.6 cm to100.6 cm over the treatments. However, the tallest plant was observed in the treatment T_9 (250 kg ha^{-1}) and the lowest (75.85 cm) at T_1 treatment i.e. control condition (no urea application), followed (85.62 cm) by T_2 treatment (125 kg soil application 50% + 10% foliar application). The plant height gradually increased with the increment of urea up to 100% recommended dose.

The treatments with respect to plant height may be ranked as: $T_9 > T_{10} > T_8 > T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$. Marginal increase in plant height with increase in nitrogen level through urea over other treatments might be due to more availability of nitrogen. Nitrogen is associated with increase in protoplasm, cell division and cell enlargement resulting in taller plants (Tisdale *et al.*, 1985). Faraji and Mirlohi (1998) reported that plant height increased with an increase in the rate of nitrogen fertilizer application 60, 90, 120 and 150 kg ha^{-1} were given before transplanting or in 2 or 3 splits while grain yield and panicle number increased with up to nitrogen 120 kg ha^{-1} but decreased at 150 kg ha^{-1}. Reddy *et al.* (1988) reported that nitrogen 120 kg ha^{-1} applied in three split dressing at transplanting (50%), tillering (25%) and panicle initiation stage (25%) gave higher plant height than the same amount of nitrogen when applied in two equal split dressing at transplanting and tillering or in a single dressing at transplanting. The results indicated that plant height increased with higher level of nitrogen applied. Application of granular urea at higher rate facilitated higher vegetative growth and hence maximum plant height attained. This result was supported by (Islam *et al*., 2009).

4.2 Dry matter (g)

Dry matter of BRRI dhan28 was significantly influenced by the soil and foliar application of urea. Dry matter content plant above soil at 60 and 75 DAT in control T_1 (no urea application), initial dry matter content lowest it was 25.6% at 60 days after transplanting and at 75 DAT it was 31.4% that mean in control plant growth very slow and water content very low so dry matter content as traditional method of urea application T_2 was followed up to $T_{10.}$ The treatments with respect to plant dry matter may be ranked as: $T_{10} > T_9 > T_8 > T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$ after day content increase high in treatment T_{10}. Chowdhury *et al*. (1994) noticed the same that the dry matter yield increased due to nitrogen applied at active tillering and panicle initiation stages. Nitrogen can increase rice grain yield by increasing the total dry matter production, the number of panicles, and the panicle length of lowland rice (Wei *et al.*, 2011).

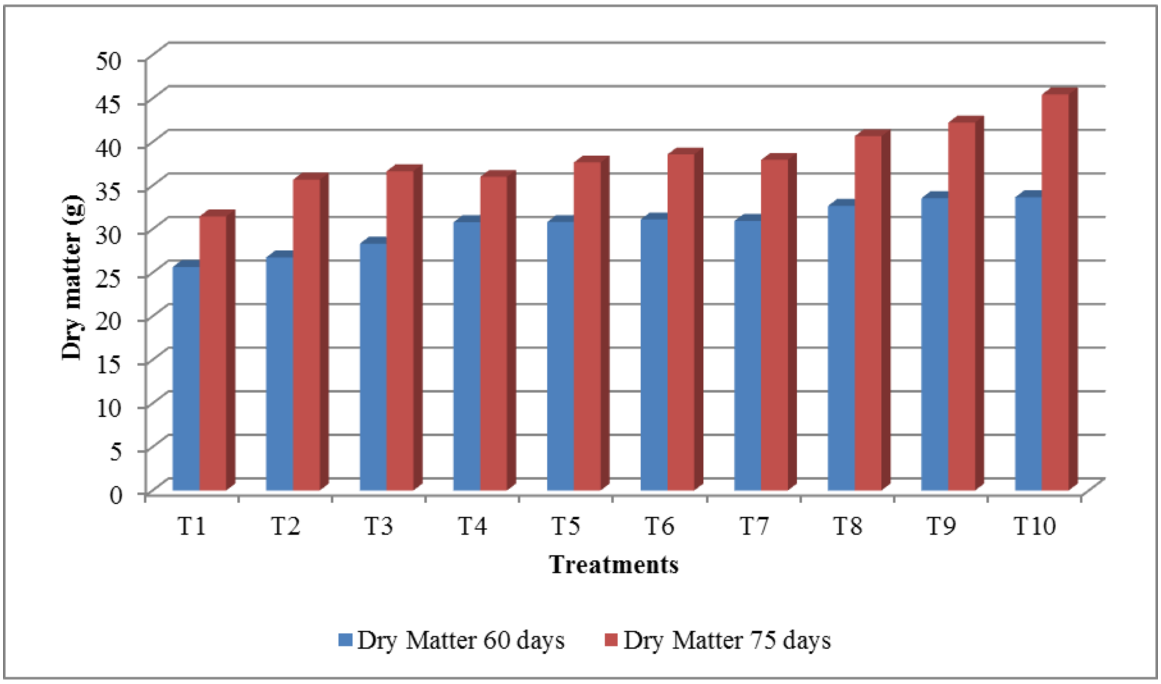


Fig. 2 Effect of soil and foliar application of urea on the dry matter (g) of BRRI dhan28

Maximum panicle dry matter (954.93) under nitrogen fertilizer treatment was observed for 300 kg ha^{-1} nitrogen and minimum of that were (892.94) obtained for 100 kg ha^{-1} nitrogen fertilizer. The heaviest panicles were recorded when nitrogen was applied at the rate of 200 kg ha^{-1} nitrogen fertilizer. This trend might be due to the role of nitrogen in crop maturation, flowering and fruiting including seed formation (Metwally *et al.*, 2011).

The results are in line with Gooding and Devies (1992) who reported better performance of wheat crop for foliar application of nitrogen. The highest rate of total dry matter production was observed from 70 to 90 DAS irrespective of nitrogen levels. These results are in line with those of Alston (1979) who reported better vegetative growth with foliar application of nitrogen.

4.3 Relative Water Content (%)

It is probably the most appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit. T_1 control was highest relative water content 99.41% (no urea application), T_2 was 82.25% followed and reduced up to T_{10}. T_9 87.85% as traditional method of urea application T_{10} was 74.48% T_{10}, T_3, T_5 showed the same result.

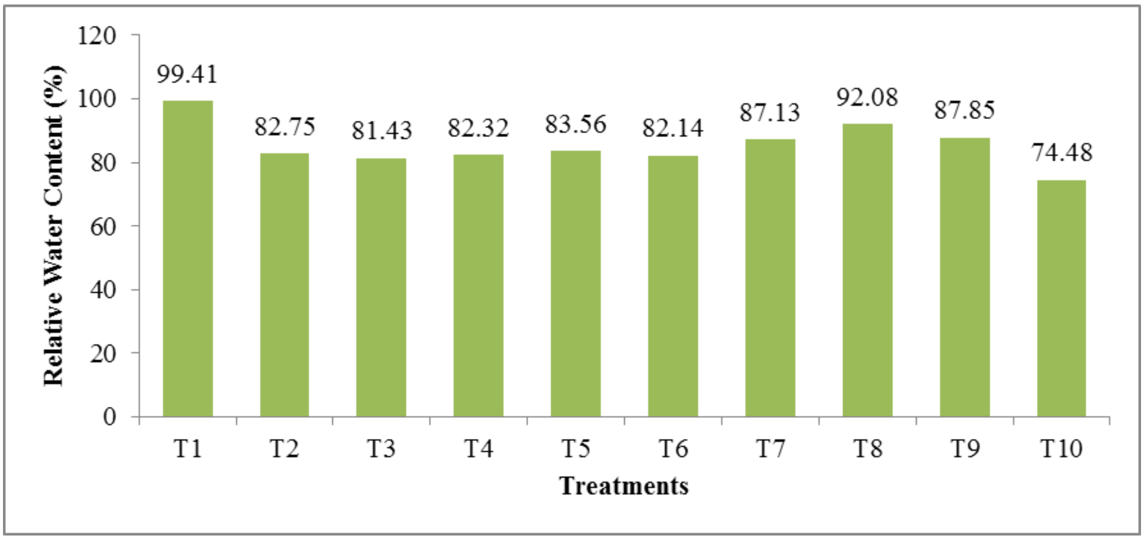


Fig. 3 Effect of soil and foliar application of urea on the relative water content (%) in rice leaf

The treatments with respect to plant relative water content may be ranked as: $T_1 > T_8 > T_9 > T_7 > T_5 > T_6 > T_2 > T_3 > T_{10}$ after day content increase high in treatment T_1. Sources of error in the estimation of RWC can be summarized as: (i) change in dry weight (mainly due to respiratory losses), (ii) increases in water content in excess of full turgidity and (iii) water accumulation in intercellular spaces (Barrs and Weatherley, 1962).

4.4 Number of effective tillers hill^{-1}

A significant variation in the number of effective tillers of BRRI dhan28 was recorded due to various treatments. It varied from 12.67 to 18.65. T_{10} show maximum tiller number that means effective and non-effective tiller number T_9 show the same result that is insignificant with T_{10}. T_8, T_7 and T_6 show highest effective tiller number which is significantly non-difference. T_1 show the lowest tiller number.

In general, the increasing trend of total tillers hill^{-1} was observed up to 45 than declined up to 75 DAT. Singh and Singh (2002) reported that increasing levels of nitrogen significantly increased total tiller hill^{-1} up to a certain stage. Tanaka *et al*. (1964) also reported the similar result that increasing the level of nitrogen increased the level of effective tillers hill^{-1}. Parvin *et al*. (2013) conducted an experiment to investigate the effect of foliar application of urea on BRRI dhan29 and found that yield and yield contributing characters (i.e. highest number of effective tillers hill^{-1}). The result of the study is in agreement with that of Ferdous (2013) who found highest number of effective tillers hill^{-1} (12.12) from foliar spray of 3% urea solution and the lowest number of effective tillers hill^{-1} (11.83) from foliar spray of 1% urea solution. The finding contrasts with the finding of Al-Amin (2010) who found highest number of effective tillers hill^{-1} (11.03) from 5-times foliar spray of urea solution.

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

Number of non effective tillers hill^{-1} was significantly influenced by nitrogen fertilizer doses and application methods of the number of non-effective tillers hill^{-1} of rice. The highest number of non-effective tillers hill^{-1} (7.865) was observed from the T_{10} whereas, the lowest (1.33) was observed from T_1. It was due to unavailability of nitrogen in later stages of rice. When plant population density optimum, then further application urea increase secondary and tertiary tiller number which is non effective tiller number. The finding contrasts with the finding of Al-Amin (2010) who obtained highest number of non-effective tillers hill^{-1} (3.23) from foliar application of 1.5% urea solution and lowest number of non-effective tillers hill^{-1} (1.57) from foliar application of 3% urea solution.

Rahman (2010) observed significant difference in producing number of total tiller hill^{-1} in boro rice cv. BRRI dhan29. Insignificant variation on production of non-effective tillers hill^{-1} was found by Khanam (2010) due to the effect of frequency of foliar application of urea solution.

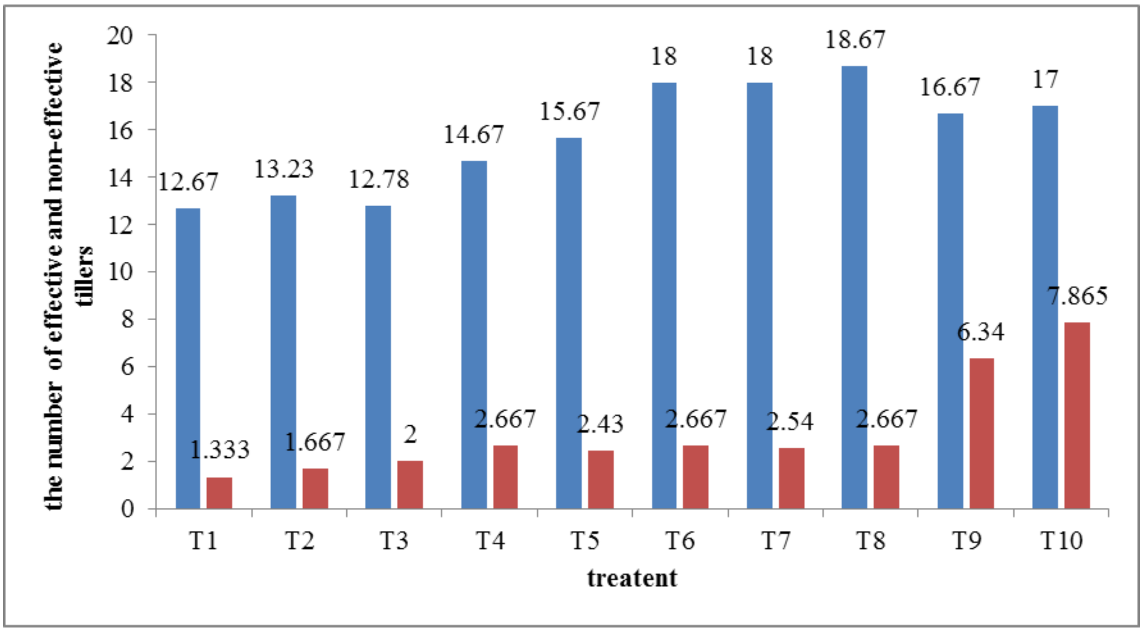


Fig. 4 Effect of soil and foliar application of urea on the number of effective and non-effective tillers of BRRI dhan28

The highest number of total tillers hill^{-1} (17.23) was also obtained by Ferdous (2013) on boro rice cv. BRRI dhan29 from foliar application of 3% urea solution.

4.6 Panicle length (cm)

Significant influence was observed on panicle length (cm) due to the different nitrogen fertilizer doses and application methods of rice. The highest length of panicle (21.43cm) was obtained from T_8. In contrast, the lowest number of panicle length (16.48cm) was recorded from the treatment combination T_1, when 70% urea as top dressing and 10% urea as foliar spray applied i.e. T_8 treatment.

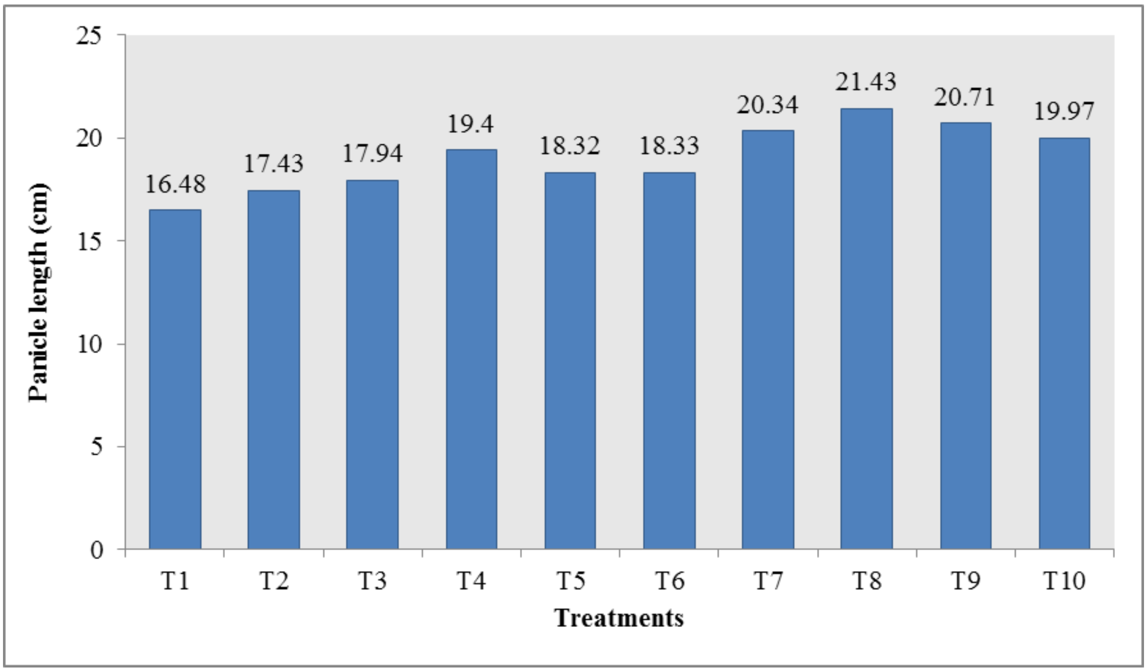


Fig.5 Effect of soil and foliar application of urea on the panicle length (cm) of BRRI dhan28

It might be due to increased level of nutrients from soil and foliar spray was also influence to elongate panicle length in rice. The treatments with respect to panicle length may be ranked as: $T_8 > T_9 > T_{10} > T_7 > T_4 > T_6 > T_5 > T_3 > T_2 > T_1$ after day content increase high in treatment T_8. Nitrogen nutrient took part in panicle formation as well as elongation and for this panicle length increased with increase of nitrogen fertilization (Alim, 2012). The result of the study is in agreement with that of Al-Amin

(2010) who obtained longest panicle length (22.03 cm) from foliar spray of 3% urea solution and lowest one (21.90 cm) from 2% urea solution. Ndaeyo *et al*. (2008) conducted an experiment in Nigeria with five rice varieties and found that higher nitrogen doses increased length of central panicle per plant. The numbers of panicles are associated with the tiller production which is most important yield attributing character (Kaushal *et al*., 2011). Maximum panicle number under nitrogen fertilizer treatment was (12.38) observed for nitrogen 300 kg ha^{-1} and minimum of that was (10.66) obtained for 100 kg ha^{-1} nitrogen fertilizer. Parvin *et al*. (2013) conducted an experiment to investigate the effect of foliar application of urea on BRRI dhan29 and found that yield and yield contributing characters (i.e. highest number of effective tillers hill^{-1}) of Boro rice *cv*. BRRI dhan29 were significantly influenced by foliar application of urea. Badole and Narkhede (2000) reported that the longest panicle length was observed from 6-times foliar spray of urea solution.

4.7 Number of fertile grains panicle^{-1}

Significant influence was observed on number of fertile grains panicle^{-1} due to nitrogen fertilizer doses and application methods of rice. The highest total number of filled grains panicle^{-1} (117.4) was observed from the T_8 and the lowest (85.34) was observed from T_1. Amount of dry matter contents in plant body, optimum tiller number as well as pollination enhanced the amount of filled grains production. This result is in agreement with the result of Dutta *et al*. (2002) who observed that yield was affected by the filled grains panicle^{-1}.Gooding & Devies (1992) reported better performance of wheat crop for foliar application of urea. Similarly, Seth and Mosluh (1981) reported marked increase in number of grains per spike of wheat when urea was applied as foliar spray.

4.8 Number of sterile grain panicle^{-1}

Nitrogen fertilizer doses and application methods showed significant variation on unfilled grains panicle^{-1} of rice. The highest total number of sterile grains panicle^{-1} (24.33) was obtained from the T_{10} and the lowest (7) was observed from T_1. It may be occurred due to lack of pollination, low dry matter content in plant, higher plant population density or pest infestation causes unfilled grain production in rice

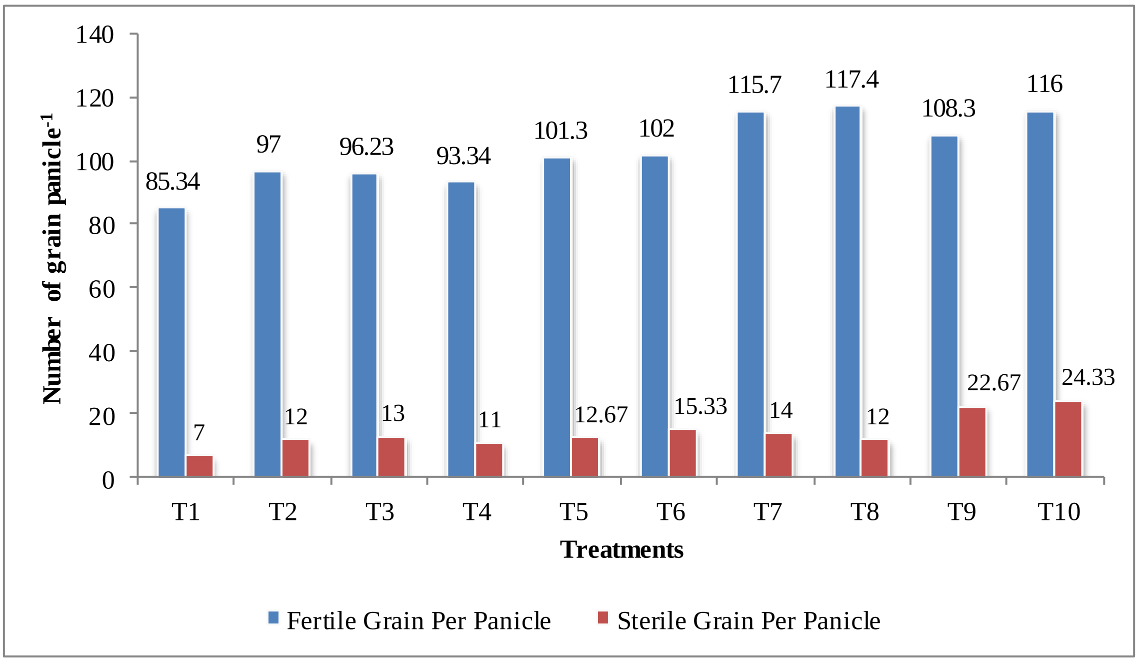


Fig. 6 Effect of soil and foliar application of urea on the number of fertile and sterile grains of BRRI dhan28

Alam *et al.* (2010) in case of that study the highest number of sterile spikelets panicle^{-1} was obtained from foliar spray of 1% urea solution and the lowest number of sterile spikelets panicle^{-1} was produced from foliar spray of 2% urea solution. A different result was reported by Alam *et al.* (2010) who 25 obtained highest number of sterile spikelets panicle^{-1} from 4 times foliar application of urea solution.

4.9 Number of total grains panicle^{-1}

Nitrogen fertilizer doses and application methods showed significant variation on total number of grains panicle^{-1} of rice. The highest total number of grains panicle^{-1} (140.3) was observed from the T_{10} and the lowest (92.34) was observed from T_1. The treatments with respect to total grains number per panicle may be ranked as: $T_{10} > T_8 > T_6 > T_9 > T_4 > T_5 > T_2 > T_3 > T_2 > T_1$ after day content increase high in treatment T_{10}.

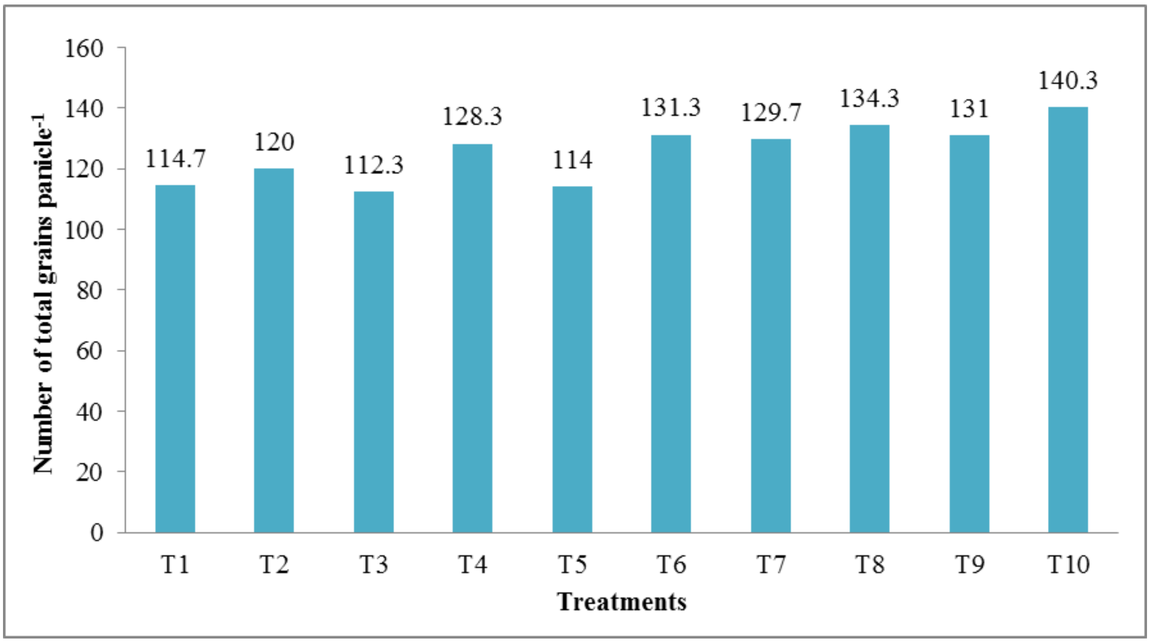


Fig. 7 Effect of soil and foliar application of urea on the number of total grains per panicle of BRRI dhan28

Rahman *et al*. (2007) conducted an experiment where the results showed that nitrogen level significantly influenced growth and yield components and maximum grains panicle^{-1} was found from nitrogen 80 kg ha^{-1}. Similar results were also found by Nerson *et al*. (1980) who observed that the increasing nitrogen supply increased the number of filled spikelets due to promotion of the rate of spikelets initiation. But Alam *et al*. (2010) obtained highest number of grains panicle^{-1} (159.74) from foliar spray of 2% urea solution.

4.10 Thousand grains weight (g)

Thousand grains weight of BRRI dhan28 was significantly influenced by the effect of nitrogen fertilizer doses and application methods. The highest thousand grains weight (24.56g) was recorded from T_8. Thousand grain weight increase with the treatment up to T_8. On the other hand, T_1 showed the lowest result (19.74g).

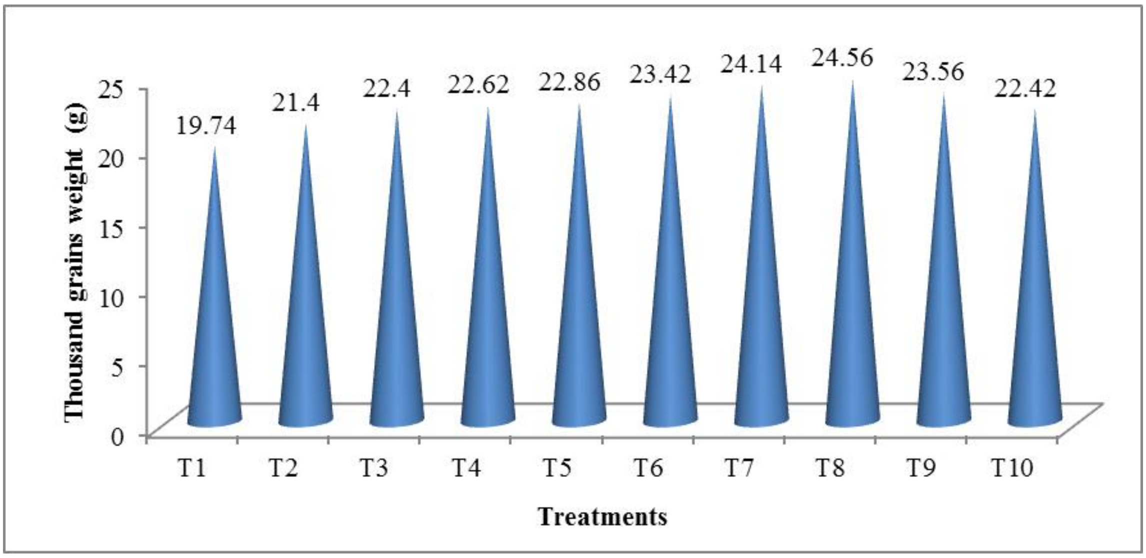


Fig. 8 Effect of soil and foliar application of urea on the 1000 seed weight (g) of BRRI dhan28

The treatments with respect to thousand grains weight may be ranked as: $T_8 > T_9 > T_{10} > T_7 > T_6 > T_5 > T_3 > T_4 > T_2 > T_1$ after day content increase high in treatment T_{10}. Awan *et al*. (2011) found that increase in grain weight at higher nitrogen rate might be primarily due to increase in chlorophyll content of leaves which lead to higher photosynthetic rate and ultimately plenty of photosynthates available during grain development. Foliar application of urea at the later growth stages of the crop might have increased the availability of nitrogen to the crop which favored enhanced accumulation of photosynthate in the grains. Rahman *et al*. (2014) reported the study of the data revealed that foliar application of urea resulted in a significant increase in thousand grain weight. The highest thousand-grain weight (26.32g) was found from 1% urea spray which was statistically identical with that of 2% urea spray (26.17g). The lowest thousand grain weight (23.10g) was noticed from the control (N_0) treatment. The results are in line with Abedin (1995) who reported significant increase in thousand-grain weight with application of nitrogen. These results are in line with Soylu *et al*. (2005) and Guenis *et al*. (2003) who reported significant increase in thousand grains weight with foliar application of nutrients.

The finding contrasts with the finding of Al-Amin (2010) who obtained highest 1000 grain weight (25.53 g) was found from 1.5% urea solution and the lowest one (23.02 g) from 3% urea solution. Badole and Narkhede (2000) observed that 6 times foliar spray of urea solution produced the highest grain yield.

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

Grain yield is the most important parameter of this study. Results of grain yield presented in showed the significant variation due to different treatments. The highest grain yield (6.314 t ha^{-1}) was recorded in T8 and the lowest yield (2.79 t ha^{-1}) in T_1, (control). The treatments with respect to plant dry matter may be ranked as: $T_8 > T_9 > T_{10} > T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$ after day content increase high in treatment T_8. Hossian *et al*. (2007) observed that nitrogen rates have significant effect on yield and yield attributes of transplanted aman rice. The highest grain yield was obtained from the application of 75% of the recommended dose (150 kg urea i.e. nitrogen 69 kg ha^{-1}) of nitrogen and the lowest from the control (0 kg ha^{-1}). Chopra and Chopra (2000) reported that application of nitrogen either 80 or 120 kg ha^{-1} improved the entire yield attributes compared to control. Results of grain yield revealed that application of 2% urea solution is not enough to produce good yield (3.80 t ha^{-1}), while with ½ soil application + 2% urea solution, the performance was better (4.97 t ha^{-1}).

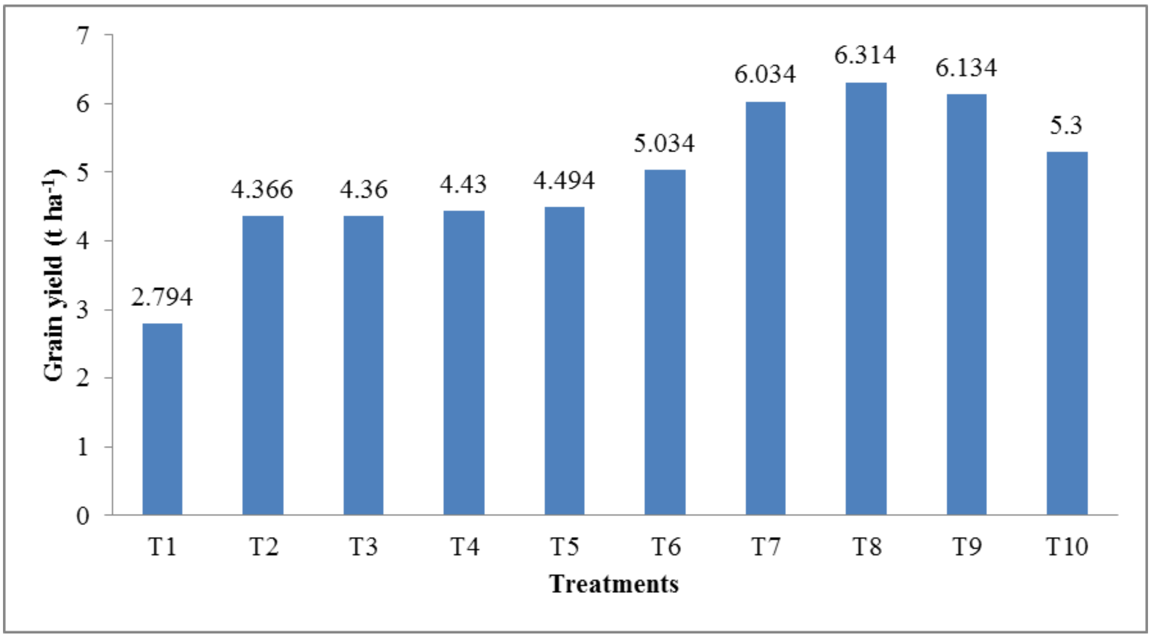


Fig.9 Effect of soil and foliar application of urea on the grain yield (t ha^{-1}) of BRRI dhan28

The reason might he a higher level of nitrogen for successful plant growth which causes negative effect. The findings are in agreement with those of Alston (1979), Strong (1982) and Gooding and Devies (1992) who reported increased grain yield for foliar application of nitrogen. Alam *et al*. (2006) observed that liquid fertilization with Magic Growth along with 75% of the recommended nitrogen fertilizer increased 10.5% grain yield with a saving of 25% of the recommended nitrogen fertilizer compared to recommended practice. Mosluh *et al*. (1978) showed that foliar feeding of urea in combination with soil application to wheat crop gave significant increase in the grain yields. Swenson *et al*. (2009) proved that foliar application before the booting stage resulted in significantly higher yields. Duraisami *et al*. (2002) reported a different result in case of grain yield. In that study highest grain yield was obtained from 2% foliar application of urea solution.

4.12 Straw Yield (t ha^{-1})

Straw yield of rice significantly was influenced by the effect of nitrogen fertilizer doses and application methods. The highest straw yield (8.372 t ha^{-1}) was obtained from T10. On the other hand, T_1 showed the lowest result (4.807 t ha^{-1}) treatment.). The straw yields obtained from different treatments followed the order: $T_{10} > T_9 > T_8 > T_7 > T_4 > T_6 > T_5 > T_3 > T_2 > T_1$. Ndaeyo *et al*. (2008) conducted an experiment in Nigeria with five rice varieties where they found that higher rates of NPK resulted in higher straw yield of rice.

Moeini *et al*. (2006) conducted a 3-year trial from 1999 to 2001 in Karaj, Iran. Treatments included 9 levels of urea application in two methods (foliar application and top dressing). The results indicated that foliar application of urea had a significant effect on yield. Rates of urea application significantly influenced the straw yield of BRRI dhan46. Singh *et al*. (2000) claimed each incremental dose of nitrogen gave significantly higher straw yield. Sarkar *et al*. (2001) reported that application of nitrogen increased straw yield significantly nitrogen up to 120 kg ha^{-1}. Foliar feeding through different fertilizers did not show beneficial effect on straw yield. Increase in the dose of nitrogen increased the straw yield and these findings are in agreement with that of Gangaiah and Rajendra prasad (1999).

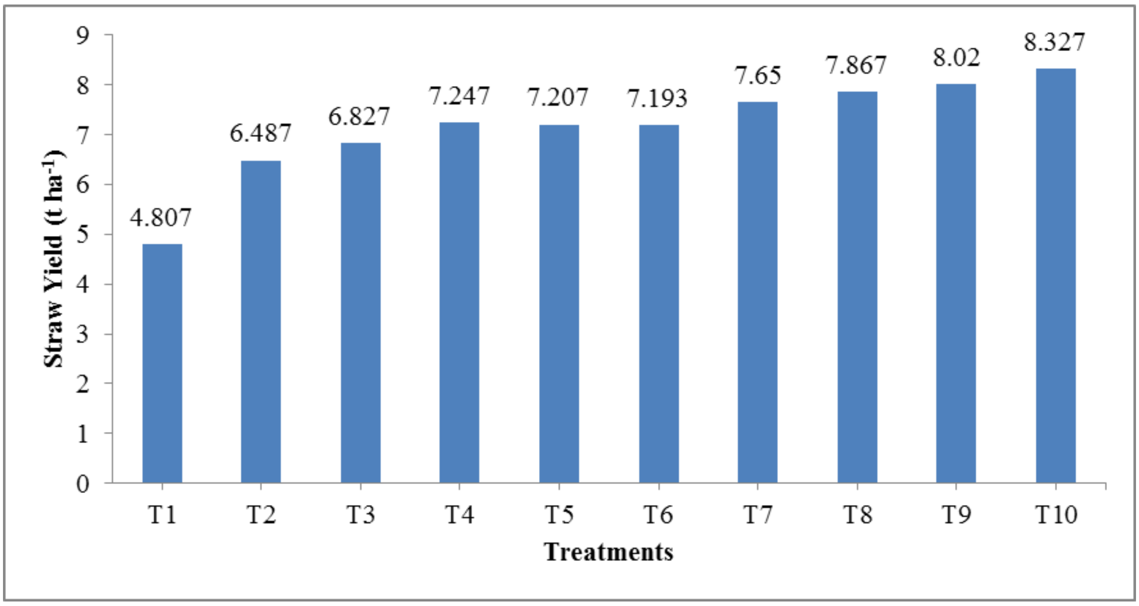


Fig.10 Effect of soil and foliar application of urea on the straw yield (t ha^{-1}) of BRRI dhan28

A different result was also reported by Duraisami *et al*. (2002) in case of straw yield. Highest straw yield was obtained from 2% foliar application of urea solution. The result of the study is in agreement with that of Rahman (2010) who attained highest straw yield from maximum times (6-times) foliar application.

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

Significant influence was observed on biological yield due to nitrogen fertilizer doses and application methods of rice. The highest biological yield (14.15t ha^{-1}) was observed from the T_9 and the lowest (7.6 t ha^{-1}) was observed from T_1. In T_9 all fertilizer applied as traditional method which contributes highest dry matter produces so total biological yield is highest. The treatments with respect to biological yield may be ranked as: $T_9 > T_{10} > T_8 > T_7 > T_6 > T_4 > T_5 > T_3 > T_2 > T_1$ after day content increase high in treatment T_9. Munshi (2005) and Chowdhury *et al*. (1999) reported that grain yield was positively correlated with biological yield in rice. The finding contrasts with the finding of Al-Amin (2010) who obtained the highest biological yield (11.62 t ha^{-1}) from 5 times foliar application of 2% urea solution.

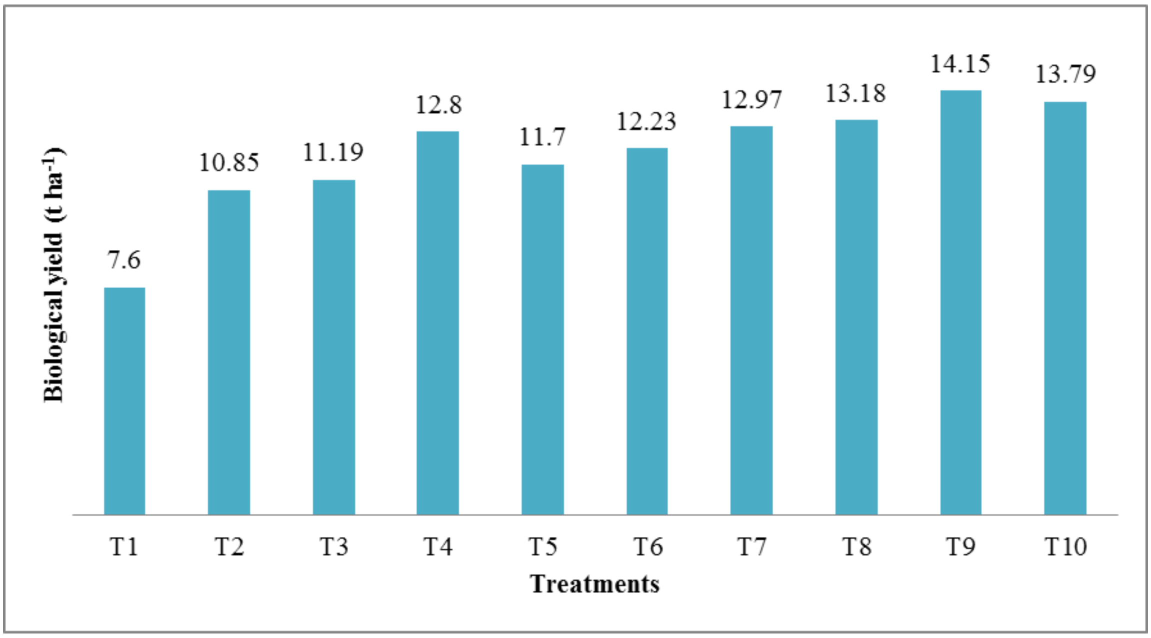


Fig.11 Effect of soil and foliar application of urea on the biological yield (t ha^{-1}) of BRRI dhan28

4.14 Harvest index (%)

Nitrogen fertilizer doses and application methods exhibited significant difference in harvest index in rice. The highest harvest index (52.51%) was obtained from T_8 and the lowest harvest index (43.56%) was recorded from T_1. Low amount of N influenced in less vegetative growth in rice that why T_1 obtained lower biological yield than other treatments. As a result, T_8 attained the highest harvest index. The treatments with respect to harvest index may be ranked as: $T_{10} > T_9 > T_8 > T_7 > T_6 > T_5 > T_4 > T_3 > T_2 > T_1$ after day content increase high in treatment T8.The result of the study is in agreement with that of Al-Amin (2001) due to the effect of foliar application of urea solution at different concentrations on harvest index. The highest harvest index (45.60%) and lowest harvest index (44.22%) was found from 3 times foliar spray of urea solution and 5-times foliar spray of urea solution respectively, by Khanam (2010).

Fig**.** 12 Effect of soil and foliar application of urea on the harvest index (%) of BRRI dhan28

Alam *et al*. (2010) observed that 2% urea solution and 4 times spray produced the highest harvest index (45.16%). On the other hand lowest harvest index (41.95%) was found from 4 times foliar spray of 1% urea solution.

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was conducted at the research field, Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during January to May, 2018 to find out the best foliar application of urea for higher productivity of boro rice cv. BRRI dhan28 with reduced nitrogen application. The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. The one factorial experiment was consisted of ten treatments *viz.* T_1= N_0 (No nitrogen applied or 0% urea i.e. control), T_2= N_{50+10}% (50% urea was applied as 2 times top dressing and 10% urea was applied as 2 times foliar spray), T_3= N_{50+15}% (50% urea was applied as 2 times top dressing and 15% urea was applied as 3 times foliar spray), T_4= N_{50+20}% (60% urea was applied as 2 times top dressing and 20% urea was applied as 3 times foliar spray), T_5= N_{60+10}% (60% urea was applied as 2 times top dressing and 10% urea was applied as 2 times foliar spray), T_6= N_{60+15}% (60% urea was applied as 2 times top dressing and 15% urea was applied as 3 times foliar spray), T_7= N_{60+20}% (70% urea was applied as 2 times top dressing and 20% urea was applied as 3 times foliar spray), T_8= N_{70+10}% (70% urea was applied as 2 times top dressing and 10% urea was applied as 2 times foliar spray), T_9 all urea were applied as traditional method (33.33% during land preparation,33.33% 25 DAT and rest 33.33% urea at 40 DAT, and T_{10}= all urea were applied as traditional method (33.33% during land preparation,33.33% after DAT and rest 33.33% applied 40 DAT +10% urea applied as 2 times foliar application at 40 and 60 DAT. For the field, the recommended dose of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and borax @ 250, 75, 100, 75, 10 and 5 kg ha^{-1}, respectively. The whole amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at final land preparation except urea. Data were recorded on different growth and yield contributing parameters. Most of the parameters showed significant difference among the treatment. Results indicated that the highest value of some parameters viz. plant height (100.6cm) T_9, highest value of these parameter *viz*. dry matter content 35.6 to 45.456%, number of non-effective tillers plant^{-1} (7.865), number of total tillers plant^{-1} (14.20), number of total grains panicle^{-1} (140), number of sterile grains panicle^{-1} (24.33), straw yield (8.317 t ha^{-1}) were observed in treatment T_{10}, highest relative water content 99.41% in treatment T_1, highest value of these parameter viz. number of effective tillers plant^{-1} (18.67), length of panicle (21.43 cm),number of fertile grains panicle^{-1} (117.4), thousand grain weight (24.56g), grain yield (6.314 t ha^{-1}), harvest index (52.51%) were observed in treatment T8. The lowest value of some parameters viz. plant height (75.85 cm), number of effective tillers hill^{-1} (12.67), number of non-effective tillers hill^{-1} (1.3333), number of total tillers hill^{-1} (13.977), panicle length (16.48 cm), number of total grains panicle^{-1} (112.3), number of fertile grains panicle^{-1} (85.34), number o sterile grains panicle^{-1} (7), thousand grain weight (19.74g), grain yield (2.194 t ha^{-1}), straw yield (4.08 t ha^{-1}) were recorded in treatment T_1. The treatment combination of T_8 (70% urea was applied as 2 times top dressing and 10% urea was applied as 2 times foliar this treatment (T_8) performed more better to all the treatments including T_9, T_{10} (recommended dose) in case of yield contributing characters and also yield. On the basis of the present investigation, the explanations of obtained results the foliar spray during the period of stage influenced to uptake the other available nutrients by the plant resulting increased the yield as well as produced good quality grains. On the other hand, 80% urea can be ensured more yield than 100% urea used as traditional method. However, to reach the more confirmation and recommendation the experiments can be repeated in different agro-ecological zone of Bangladesh.

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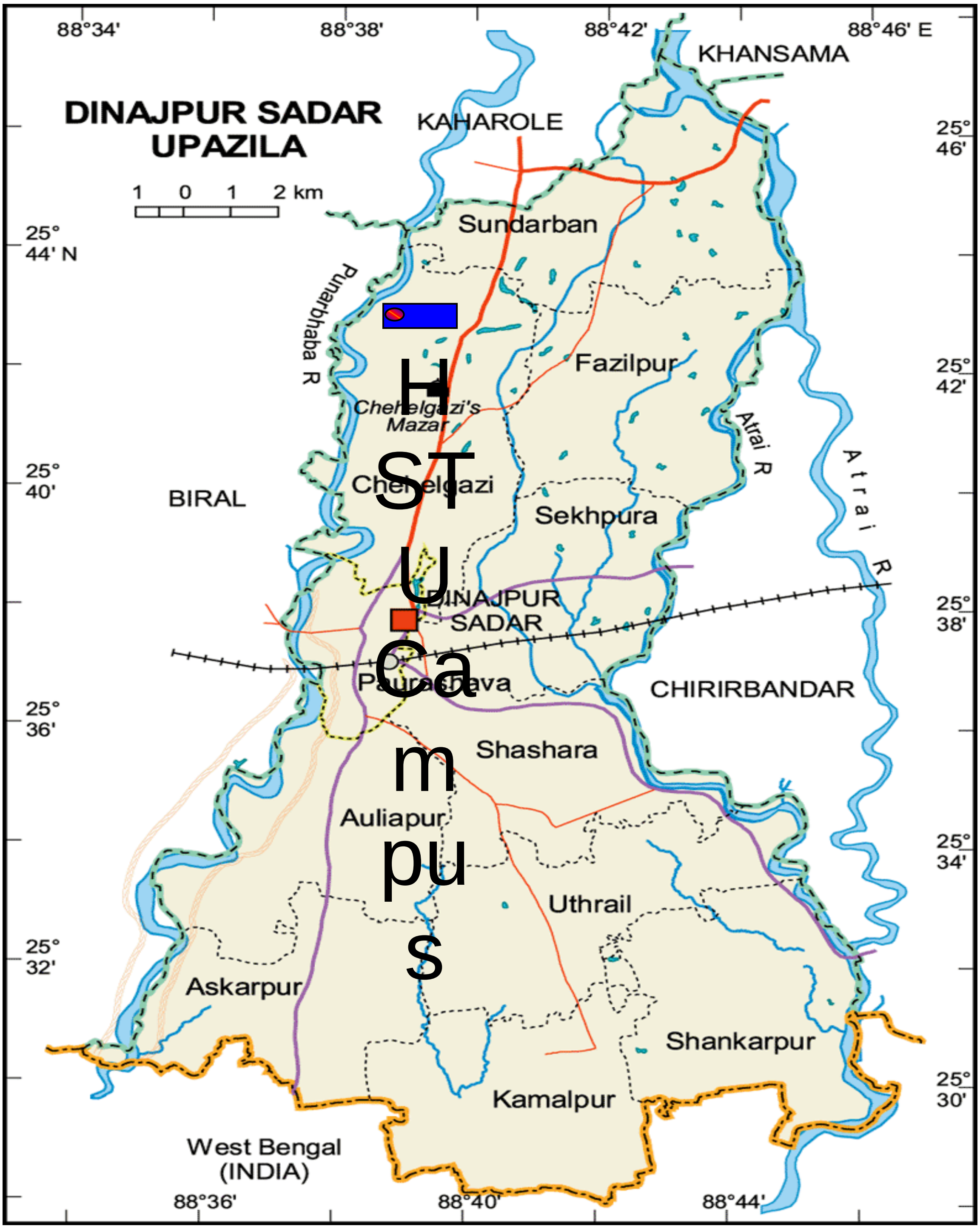
APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur, Sadar Upazila) showing the research plot



Appendix II. Morpho-physiochemical properties of HSTU, Dinajpur soil with critical value and their extraction methods

Morphological soil properties			
Properties	Nutrient status	Critical value	Extraction methods
AEZ	AEZ-1: Old Himalayan Piedmont Plain		
Land type	High land		
General soil type	Non-calcareous brown Floodplain sols		
Soil series	Ranisankil		
Topography	Levelled		
Drainage	Well drainage system		
Flood level	Above flood level		
Geographic position	25.42^{o} North Latitude 88.39^{o} East Longitude 37.35m above sea level		

Physiological soil properties			
Properties	Value (%)	Critical value	Extraction methods
Sand	58		
Silt	28		
Clay	14		
Textural class	Sandy loam		Hydrometer method (Black, 1965). Determined by Marshall's Triangular Coordinates by USDA system.

Chemical soil parameters

Properties	Value (%)	Critical value	Extraction methods
Soil pH (1:1.25, Soil: H_2O)	5.41		Glass-electrode pH meter with 1:1.25 soil-water ratios (Page ET AL.,1982).
Organic matter	1.48		Wet oxidation method (Black, 1965). Calculated by Van Bemmelenfactor 1.73 (Piper, 1966).
N (%)	0.08		Micro-Kjeldahlmethod (Bremmer And Mulvaney, 1982).
Available P (ppm)	11.20		Molybdate blue ascorbic acid method (Bray and Kurtz, 1945).
Exchangeable K (meq %)	0.10		Determined by Flame photometer
Exchangeable Ca (meq %)	2.48		By Atomic Absorption Spectrophotometer (AAS) (Knudsen ETAL., 1982).
Exchangeable Mg (meq %)	0.29		Extractable method (Hunter, 1972).
Available S (ppm)	17.29		Turbidity method using $BaCl_2$ (Fox ETAL., 1964).
Available B (ppm)	0.13		Mono-calcium bi-phosphate method and the determination by Spectrophotometer following Azomethine Hmethod (Page ET AL.1982).
Available Zn (ppm)	0.90		Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).
Available Fe (ppm)	51.90		Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).
Available Mn (ppm)	12.13		Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).
CEC			Sodium acetate saturation method (Rhoades, 1982).

Source: Department of Soil Science, HSTU, Dinajpur.

Appendix III. Monthly air temperature, rainfall and relative humidity during the growing per from December, 2017 to May, 2018

Month	Air temperature (^{0}**C)**			Rainfall (mm)	Relative humidity **(%)**
	Maximum	Minimum	Average		
December 2017	28	13.1	20.55	0	80
January 2018	25	9.7	17.35	4	81
February 2018	28.1	12.5	20.3	0	77
March 2018	28.7	15.1	21.9	97	78
April 2018	31.4	19.5	25.45	207	83
May 2018	33.3	22.3	27.8	127	81