A SEMINAR PAPER ON

Nitrogen Use Efficiency in Cereal Crops in Bangladesh

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ABSTRACT

Cereal crops play a vital role in ensuring national food security of Bangladesh. Cereal crops contribute a lot to the agricultural sector of Bangladesh. Cereal crops in Bangladesh especially rice and wheat are very much responsive to nitrogenous fertilizer. The present condition of nitrogen use efficiency (NUE) in cereals is not up to the mark. The efficiency of applied nitrogenous fertilizers is less than 50% due to different types of losses such as denitrification, volatilization, surface runoff and leaching from soil-plant system. Improvement of present condition of nitrogen use efficiency (NUE) is very essential to increase the production of cereal crops as well as to reduce the cost of production. Urea super granule (USG) can play a great role as a nitrogenous fertilizer to improve the efficiency of nitrogen use in cereal crops. Besides, crop improvement and need-based fertilizer management are very important. Nitrogen use efficiency need to be in an acceptable limit so that grain yield can be improved through optimum application of nitrogen.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Bangladesh is an agricultural country having a higher rate of population growth. It is one of the most densely populated nations in the world. The economy of Bangladesh is largely dependent on its agricultural sector. More than 80% population of the country depends on agriculture directly or indirectly as their chief source of livelihood (Shah *et al*., 2008). The main purpose of agriculture is to provide food for the overgrowing population. To meet the food requirement of almost 160 million people it needs to produce a huge amount of food every year. Though Bangladesh has achieved food security in the recent past but it still faces huge challenges in maintaining this achievement. This is because of its overgrowing population, changes in food habits and little or no space for the expansion of cropland as well as cropping intensity (Timsina *et al*., 2016). In Bangladesh, the structure of the agricultural sector is largely dependent on the cereal crops production like other South-Asian countries (Ghose *et al*., 2014).

Cereals are generally the crops of Gramineae family. They are usually grown for their palatable, nutritious and starchy seeds. According to the concept of FAO, cereals are refers to crops harvested for their dry grain only. For marketing purpose, the production data on cereals are stated in terms of clean, dry mass of grains with a moisture content of 12 to 14 percent. In addition to moisture content and other inedible elements (e.g. cellulose), cereal grains also contain a trace amount of minerals and vitamins, carbohydrates mainly starches which comprise about 65 to 75 percent of their whole as well as proteins which is 6 to 12 percent and about 1 to 5 percent fat (FAO, 2014). In Bangladesh major cereal crops including rice (aus, aman, boro), wheat and minor cereal crops like, maize, barley, cheena, jowar, bajra, kaon etc. covered a total area of 30.03 million acres of land with the production of 38.33 million metric tons of food grains. Major cereals covered a land area of 29.22 million acres with the production of 36.05 million metric tons of food grains while minor cereals covered a land area of only 0.81 million acres with the production of 2.28 million metric tons of food grains. Among the major cereals rice (aus, aman, boro) covered a land area of 28.20 million acres with the production of 34.71 million metric tons of food grain and wheat covered a land area of 1.07 million acres with the production of 1.34 million metric tons of food grains (BBS, 2015).

Rice occupies the top position among all the cereals with almost 75 percent of the total cropped area under rice cultivation. It easily can be said that the main crop for entire agricultural sector of Bangladesh is rice. On the other hand, wheat and maize have some presence in Bangladesh among the other cereals (Ganesh-Kumar *et al*., 2012).

For improving crop yields and farm profit fertilizer is considered as the principal inputs. In case of agricultural sector of Bangladesh this is also true, because the country has hardly any possibility of expanding its cultivable land area. For this, the production of food of this country can be accelerated through improving irrigation facilities alongside better practice of fertilizer as well as high yielding variety (HYV) (Shah *et al*., 2008). Fertilizer is mainly recommended for crop plants to supply essential nutrient element throughout the growth and development period. Among the all essential nutrient elements nitrogen is needed most for crop plants. To supply nitrogen mainly urea fertilizer is used which contains about 46% nitrogen. Plants require in large amounts of nitrogen for growth and development. High nitrogen fertilization enables maximum crop yields which are the scenario of industrial countries in the last 50 years. There is a dramatic increase in the use of synthetic nitrogen fertilizers in the last 50 years to meet the agricultural needs of a growing population (Conant *et al*., 2013). On the other hand, in case of developing countries, there is limited access to nitrogen fertilizer as well as inadequate nitrogen nutrition consequences in low crop productivity which ultimately leads to a reduction in food supply (Brown *et al*., 2009).

In most terrestrial ecosystems the availability of nitrogen is one of the major limiting factors for primary productivity (Cole *et al*., 2008). The farmers of Bangladesh use a considerable amount of urea fertilizer to meet the requirement of nitrogen for the production of rice and wheat. But a large portion of this fertilizer can not be utilized by the crop plants due to lower nitrogen use efficiency (NUE). Crop plant can use only 30-50% applied nitrogen efficiently which is sometimes even lower than that value (Prasad *et al*., 1979). Nitrogen use efficiency (NUE) is very important factor for crop production, particularly for cereal crops. The value of NUE differs from crop to crop. Efficient use of nitrogen is very important to maintain the economic sustainability of cropping systems. The definition of NUE depends on the purpose to which the indicator will be placed. By using partial nutrient balance NUE can be measured. This is also known as the removal/use ratio or the output/input ratio. This indicator is resultant from the totality of nitrogen in all of the yields removed from the field (i.e., the harvested crop) and the totality of whole inputs of N to the crop field, farm or region. (i.e., fertilizer, imported animal manure, compost, green manure or other soil amendments, imported animal feed, and biological N fixation). The value of NUE reflects the quantity of nitrogen recovered in yield which is related to the quantity of nitrogen incoming to the site (Norton *et al*., 2015). The lower value of NUE in cereal crops is occurred due to different types of losses such as ammonia volatilization, leaching of nitrate nitrogen, surface run-off, and denitrification. This lower NUE value is responsible for higher cost of crop production as well as for environmental pollution. Enhancing nitrogen use efficiency is required for the improvement of crop yields, to lessen the cost of production and to uphold environmental quality. Nitrogen use efficiency in agriculture can be improved through integrated nitrogen management approaches which take into consideration better-quality fertilizer accompanied by proper soil and crop management practices (Fageria *et al*., 2005).

Keeping these above considerations in view, the present study has aimed with the following objectives:

1. To review nitrogen use efficiency in cereal crops in Bangladesh, and
2. To know the approaches to improve nitrogen use efficiency in cereal crops.

CHAPTER II

MATERIALS & METHODS

This paper is exclusively a review paper so that all of the information has been collected from the secondary sources. During the preparation of the review paper, I went through various relevant books, journals publications etc. The related topics have been reviewed with the help of library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Research Institute (BARI) and Bangladesh Rice Research Institute (BRRI) and internet browsing. After collecting all the available information, it has been presented as per the objectives of this paper.

CHAPTER III

REVIEW OF FINDINGS

Nitrogen (N)

Nitrogen is a primary essential nutrient for plant growth and development. In many organic compounds (protein, nucleic acids, alkaloids etc.) nitrogen is acting as principal component. Nitrogen is an essential part of adenosine diphosphate (ADP) and adenosine triphosphate (ATP). ADP and ATP play a key role in energy use, transfer and release in various metabolic processes of plants (Riedell *et al*., 1996). Nitrogen is also an important part of nucleic acid (deoxyribonucleic acid and ribonucleic acid) which play a vital role in plants genetic inheritance. Chlorophyll which acts as a factory for plants photosynthetic activity is composed of nitrogen. Nitrogen has special significance in absorption of water and nutrients through improving the root system (Fageria and Barbosa, 2001).

Nitrogen use efficiency (NUE)

For achieving high yields with the minimization of the rates of nitrogen fertilization and limited environmental side effects related to nitrogen leaching, optimization of fertilizer use and improvement of NUE is needed now (Agostini *et al*., 2010; Burns, 2006). Nitrogen use efficiency can be calculated through evaluating the ability of crops to uptake nitrogen from the soil (Burns, 2006), and the efficiency with which the absorbed nitrogen is used by the crop for its growth and yield (Schenk, 2006). The value of NUE may differ within the same crop because it depends on different organs and mechanisms and on different environmental factors (Burns, 2006). NUE can be calculated as the ratio between the amount of fertilizer N removed with the crop and the amount of fertilizer N applied (Brentrup, 2010). Agronomic nitrogen use efficiency or simply nitrogen use efficiency (NUE) can be calculated with the help of the following formula (Krupnik *et al*., 2015):

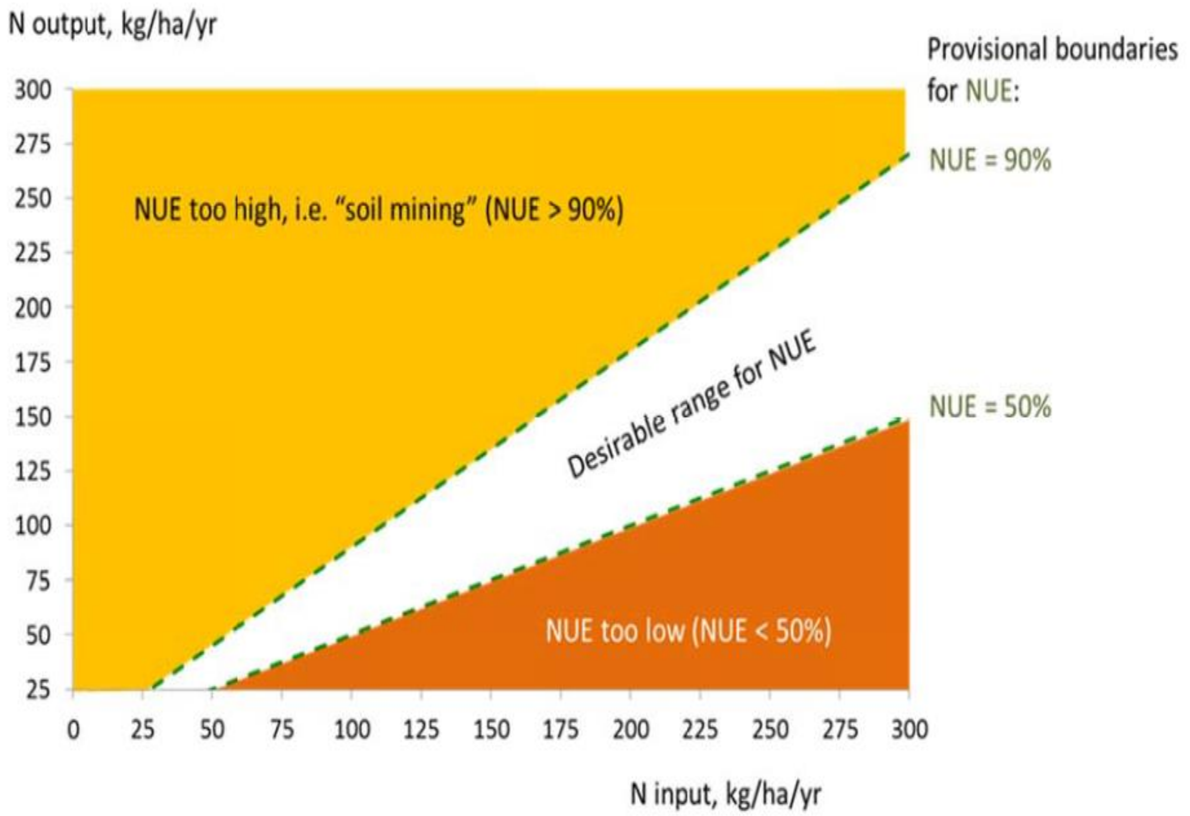
Agronomic nitrogen use efficiency = $(GY_F - GY_0) / F_N$

Where, GY_F = Grain yield (kg ha^{-1}) in nitrogen-fertilized plot; GY_0 = Grain yield (kg ha^{-1}) in zero nitrogen-fertilized plot or control plot and F_N= Total applied nitrogen fertilizer (kg ha^{-1}).

A graphical representation of NUE

Nitrogen use efficiency is reported as percentage or mass fraction, together with the yield (nitrogen output) in kg ha^{-1} yr^{-1}, nitrogen surplus in kg ha^{-1} yr^{-1}, a description of the system, the period and also possible changes in the nitrogen stock of the system (Panel, 2015).

Different boundaries and desirable range for NUE are shown in **figure 1**.



(Source: Panel, 2015)

Figure 1. Different boundaries and desirable range for NUE

Crop plants can utilize only half or less than that amount of applied nitrogen. There are several factors which are responsible for this lower nitrogen use efficiency. The main reason behind this is the higher susceptibility of applied nitrogen towards diffent losses. Ammonia volatilization, leaching of nitrate nitrogen, surface run-off, and denitrification are some of the way through which loss of applied nitrogen occurs. Degree of these losses depends on several factors such as soil type, crop species, fertilizer doses, management practices, environmental condition, and so on.

Factors influencing nitrogen use efficiency (NUE)

Efficient use of nitrogen by crops depends on a number of factors. These can be discussed in three parts:

- Demand of N: Demand of N by crops related to climatic variables such as ambient temperature, solar radiation, amount of rainfall and relative humidity. These factors and their interaction influence crop demand of N as well as health of crop plants (Kravchecko *et al*., 2003).
- Supply of N: Supply of N depends on mineralization of N from soil organic matter as well as N through chemical fertilizers which are applied externally. The contribution of chemical fertilizer to N supply is higher than soil organic matter because of their higher mineralization rate. Mineralization rate of N of soil is mostly influenced by some factors such as moisture availability, temperature, aeration and activity of microbial population. For example, low soil moisture with mild soil temperature can reduce the rate of N mineralization from organic sources (Giller *et al*., 2004).
- Losses of N: Nitrogen demand can be increased due to optimum conditions for plant growth and development. But, because of higher rate of N loss low recovery of applied N occurs (Mosier *et al*., 2001).

Approaches to improve nitrogen use efficiency

- Soil, water and crop management
- Site specific nitrogen management
- Conservation agricultural practices
- Use of controlled and slow release fertilizers
- Use of manure and organic amendments
- Improved crop varities
- Methods of fertilizer application
- Crop improvement

Among the cereals rice and wheat are mainly grown for consumption purpose in Bangladesh. To meet the requirement of overgrowing population farmers of this country need to increase the production every year. For this, they use a huge amount of chemical fertilizers along with other improved technologies such as improved seeds, HYV (High Yielding Varieties), pesticides, modern technologies and management practices.

Nitrogen requirement for crop production is mainly fulfilled through urea fertilizer. The demand, production, total sales and import scenario of urea in Bangladesh from 2008 to 2010 are shown in **table 1**.

Table 1. Demand, production, total sales and import scenario of urea in Bangladesh

Year	Domestic production (Lakh metric tons)	Total estimated demand (Lakh metric tons)	Import (Lakh metric tons)	Total sales (Lakh metric tons)
2008-09	12.00	28.18	13.75	25.33
2009-10	11.00	29.51	14.65	24.06

(Source: BBS, 2015)

Rice

Rice (*Oryza sativa* L.) takes the first position among the cereal crops in Bangladesh. In Bangladesh rice is cultivated throughout the year as aus, aman or boro. Aman (broadcast and transplanted) is generally cultivated in December-January, boro in March-May, and aus in July-August cropping seasons. Rice contains a considerable amount of carbohydrate, protein, and traces of minerals, fat and vitamins. Rice is very much responsive to nitrogen. It requires a large amount of nitrogen throughout its life cycle. But nitrogen use efficiency in rice is less than 50% of applied nitrogen.

An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Boro season of 2012 which was arranged in a randomized complete block design with three replications to examine the effect of prilled urea (PU), and urea super granule (USG) alone with the combination of poultry manure (PM) or cowdung (CD) on ammonium nitrogen content of rice field with nitrogen use efficiency (NUE) and the yield of BRRI dhan50. Nitrogen content in poultry manure was 1.18% and in cowdung 0.57%.

Six treatments were applied which are T1 (Control), T2 (78 kg N ha^{-1} from USG), T3 (136 kg N ha^{-1} from PU), T4 (58 kg N ha^{-1} from USG), T5 (58 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure) and T6 (58 kg N ha^{-1} from USG + 5 t ha^{-1} cowdung). Recommended doses of phosphorus, potassium, sulphur and zinc fertilizers were applied to all plots (Husan *et al*., 2014).

Grain yield and nitrogen content in grain of BRRI dhan50

The effect of PU and USG with or without organic manures on grain yield and nitrogen content in grain of BRRI dhan50 is shown below (**Table 2**).

Table 2. Effect of PU and USG with or without organic manures on the nitrogen content by BRRI dhan50

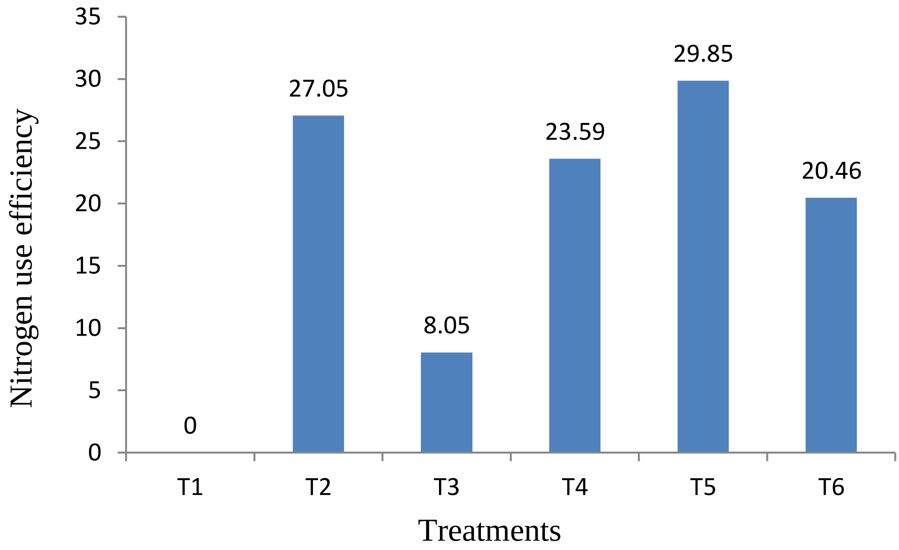
Treatments	Grain yield (kg/ha)	N content (%) in grain
T1 (control)	2431	1.03
T2 (78 kg N ha^{-1} from USG)	4541	1.30
T3 (136 kg N ha^{-1} from PU)	3526	1.10
T4 (58 kg N ha^{-1} from USG)	3800	1.16
T5 (58 kg N ha^{-1} from USG + 3 ton ha^{-1} PM)	4700	1.32
T6 (58 kg N ha^{-1} from USG + 5 t ha^{-1} CD)	3925	1.17

(Source: Husan *et al*., 2014)

The yield of grain was varied from 2431 kg/ha to 4700 kg/ha and nitrogen content in grain varied from 1.03% to 1.32%. The highest grain yield (4700 kg/ha) was found at T5 (58 kg N ha^{-1} from USG + 3 ton ha^{-1} PM) and the lowest grain yield (2431 kg/ha) was observed at T1 (control). The highest nitrogen content in grain was 1.32% which was observed at T5 (58 kg N ha^{-1} from USG + 3 ton ha^{-1} PM) and the lowest value was 1.03% which was observed at T1 (control). In T_5 combined application of USG and poultry manure improved the percentage of N content in rice grain. The combined effect of USG and poultry manure was more pronounced than the other treatments in improving the grain yield as well as the percentage of nitrogen content in grain of BRRI dhan50. It also can be seen that the combination of USG and cow dung also improved the grain yield and percentage of nitrogen content in grain but the effect was less than T5. Improvement in the percentage of nitrogen content in rice grain due to the application of fertilizers and manures was also reported by Bhaskaram and Krisna, (2009).

Nitrogen use efficiency (NUE) in BRRI dhan50

Relationship between the amount of fertilizer nitrogen taken up and used by the crop versus the amount of fertilizer nitrogen lost can be indicated through nitrogen use efficiency. The effect of nitrogen fertilizer in grain yield of rice can be represented by using nitrogen use efficiency. The values of NUE for the treatments are shown below (**Figure 2**).



T1= 0 kg N ha^{-1}; T2=78 kg N ha^{-1} from USG; T3=136 kg N ha^{-1} from PU; T4=58 kg N ha^{-1} from USG; T5=58 kg N ha^{-1} from USG + 3 ton ha^{-1} PM and T6=58 kg N ha^{-1} from USG + 5 t ha^{-1} CD.

(Source: Husan *et al*., 2014)

Figure 2. Nitrogen use efficiency (NUE) of BRRI dhan50 as influenced by different treatments.

The value of NUE was highest in T5 (58 kg N ha^{-1} from USG + 3 ton ha^{-1} PM) which was 29.85 and the value of NUE was lowest in T3 (136 kg N ha^{-1} from PU) which was 8.05. In case of T6 (58 kg N ha^{-1} from USG + 5 t ha^{-1} CD), the value of NUE was 20.46 which indicate that the effect of cow dung in combination with USG is lower than the combination of poultry manure and USG (T5). According to the result, there is an indication that the combined application of USG and poultry manure in rice field declines the losses of nitrogen which increases the efficiency of nitrogen utilization. It can be seen that NUE value was higher in case of USG. This might be happen due to the localized application of USG which minimized the losses as well as increased NUE value. Similar type of results was also reported by Akter *et al.* (2012) and Jahan *et al.* (2014).

Another experiment was carried out at the farm of Bangladesh Rice Research Institute, Gazipur during boro season of 2013-14 and 2014-15 to figure out nitrogen use efficiencies and response of BRRI dhan28 and BRRI dhan29 under four N management practices. The practices were 1) urea application by prilled urea (PU) applicator, 2) urea super granule (USG) (2.7 g) application by USG applicator, 3) hand broadcasting of prilled urea in three splits and iv) without urea (control). Factorial randomized complete block design with three replications was conducted at that experiment (Bhuiyan *et al*., 2016). The effect of varieties and nitrogen management on yield during boro season is shown in **table 3**. The highest value for 1000 grain weights for BRRI dhan28 was 23.24 gm which was found in case of USG and the lowest value (20.61 gm) was observed in case of control. For grain yield the highest value (6.46 t/ha) was found for PUB and the lowest value (2.59 t/ha) was observed for control. In case of BRRI dhan29, for 1000 grain weights the highest value (22.66 gm) was due to PUB while the lowest (21.27 gm) was for control. For grain yield, the highest value (7.38 t/ha) was due to PUB while the lowest (3.11 t/ha) was for control.

Table 3. Effect of varieties and nitrogen management on yield during boro season, BRRI, Gazipur

Nitrogen management	Nitrogen rates (kg/ha)	1000 grain weights (gm)	Grain yield (t/ha)
		BRRI dhan28	
Control	0	20.61	2.59
PUA	87	21.61	5.47
USG	75	23.24	6.30
PUB	124	22.09	6.46
		BRRI dhan29	
Control	0	21.27	3.11
PUA	87	22.07	6.75
USG	75	21.79	6.65
PUB	124	22.66	7.38

Control= No urea, PUA= Prilled urea applicator, USG= Urea super granule PUB= Prilled urea broadcasting (Source: Bhuiyan *et al*., 2016)

Nitrogen use efficiencies (NUEs) in BRRI dhan28 and BRRI dhan29

Effect of different nitrogen management and rates of nitrogen on nitrogen use efficiencies for variety and nitrogen interaction during boro sesson, 2014 at BRRI, Gazipur is shown below (**Table 4**). In case of BRRI dhan28, the highest value of agronomic nitrogen use efficiency was 49 kg/ha which was found for USG while the lowest value (31 kg/ha) was observed for PUB. For BRRI dhan29, the highest agronomic nitrogen efficiency value (47 kg/ha) was found for USG and lowest (42 kg/ha) was observed due to the application of PUA.

Table 4. Effect of different nitrogen management and rates of nitrogen on nitogen use efficiencies for variety and nitrogen interaction

Nitrogen management	Nitrogen rates (kg/ha)	Agronomic nitrogen use efficiency (kg/ha)
	BRRI dhan28	
PUA	87	33
USG	75	49
PUB	124	31
Average		38
	BRRI dhan29	
PUA	87	42
USG	75	47
PUB	124	34
Average		41

Control= No urea, PUA= Prilled urea applicator, USG= Urea super granule PUB= Prilled urea broadcasting (Source: Bhuiyan *et al*., 2016)

On an average the agronomic nitrogen efficiency value was highest for BRRI dhan29 (Bhuiyan *et al*., 2016). It also can be seen that NUE value is higher for USG application in both varieties. This might be happen due to the localized application of USG which minimized the losses of nitrogen, store nitrogen for longer period as well as improve nitrogen use efficiency of the crop.

Wheat (*Triticum aestivum* L.) takes the position of second most important cereal crop of Bangladesh after rice. The yield of wheat is significantly influenced by different varieties, inputs requirement and growth cycle. For this, the farmers of Bangladesh prefer to use diverse varieties with several yield contributing characters which are different from one variety to another (Kumar *et al.* 2011). Due to varietal diversity the growth and development process of wheat plants differ under a given agro-climatic condition (BARI, 2010).

To know the effect of variety and different nitrogen level an experiment was conducted at farmer's field of Siroil village under the Godagari Upazila of Rajshahi, Bangladesh during the period from November 2013 to April 2014. Method of split-plot design with three replications were followed for this experiment where two varieties of wheat, Bijoy (V1) and Prodip (V2) were assigned in main plots and four nitrogen levels, N0 = 0 kg N/ha, N1 = 60 kg N/ha, N2 = 120 kg N/ha and N3 = 180 kg N/ha were assigned in sub-plots. All the plots received recommended dose of phosphorus, potassium, sulphur and zinc (Rafii *et al*., 2017). The effect of variety and nitrogen rates on yield of wheat are shown in **table 5**.

Table 5. Effect of variety and nitrogen level on yield and yield components of wheat

Variety	1000-grain weight (gm)	Grain yield (t/ha)
V1	43.57	2.52
V2	49.25	2.74
Nitrogen level		
N0	39.79	2.44
N1	45.26	3.53
N2	49.11	4.28
N3	51.48	4.96

(Source: Rafii *et al*., 2017)

In case of 1000 grain weights the highest value (51.48 gm) was observed at N3 (180 kg N ha^{-1}). The lowest value (39.79 gm) was observed at N0 (control). After N3 the highest value was obtained from N2 (120 kg N ha^{-1}) which was 49.11 gm and then from N1 (60 kg N ha^{-1}) which was 45.26 gm. In case of grain yield the highest value (4.96 t/ha) was observed at N3 (180 kg N ha^{-1}) and the lowest value (2.44 t/ha) was found at N0 (control). Likewise 1000 grain weights, after N3 the highest value for grain yield was observed at N2 (120 kg N ha^{-1}) which was 4.28 t/ha and then at N1 (60 kg N ha^{-1}) which was 3.53 t/ha (**Table 5**).

Effect of variety and nitrogen level on nitrogen use efficiency of wheat

Effect of variety and nitrogen level on nitrogen use efficiency of wheat is shown in **table 6**. In case of variety, the highest NUE value (29.46) was found for the variety Prodip (V2) and lowest (27.18) was for the variety Bijoy (V1).

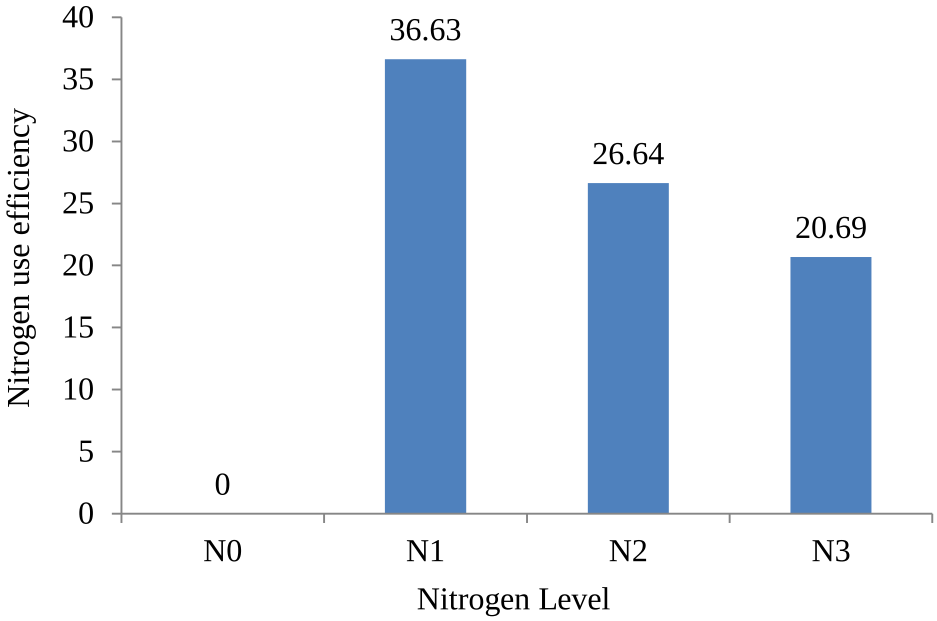
Table 6. Effect of variety and nitrogen level on nitrogen use efficiency of wheat

Variety	Nitrogen use efficiency
V1	27.18
V2	29.46
Nitrogen level	
N0	-
N1	36.63
N2	26.64
N3	20.69

(Source: Rafii *et al*., 2017)

The values of NUE varied from 20.69 to 36.63. The values of NUE for different nitrogen levels are shown in **figure 3**. The value of NUE was highest in N1 (60 kg N ha^{-1}) which was 36.63 and the value of NUE was lowest in N3 (180 kg N ha^{-1}) which was 20.69. The value of NUE at N2 (120 kg N ha^{-1}) was 26.64. It can be seen that the value of NUE was decreasing with the increase of nitrogen doses.

This might be happen due higher amount of losses of applied nitrogen as well as rapid growth of microbial population which compete for nitrogen with crop plants and decrease the NUE value for plants.



N0= 0 kg N/ha; N1= 60 kg N/ha; N2= 120 kg N/ha and N3= 180 kg N/ha

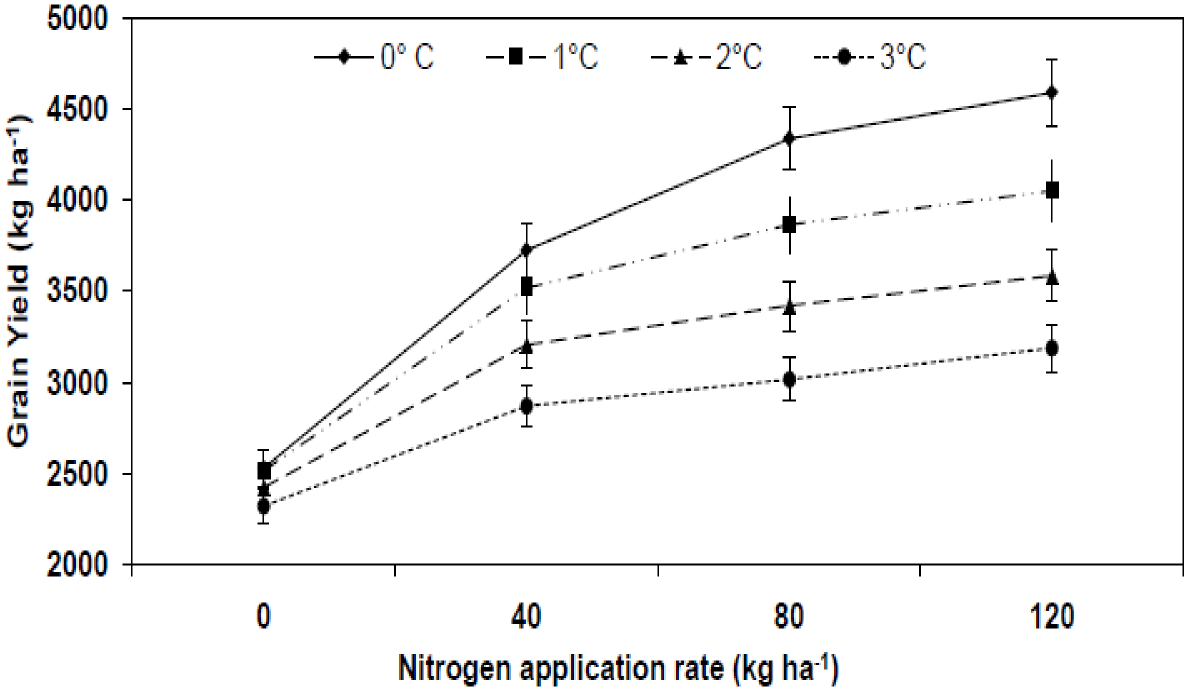
(Source: Rafii *et al*., 2017)

Figure 3. Nitrogen use efficiency of wheat as influenced by different nitrogen level.

Effect of different nitrogen rates and temperature level on grain yield in BARI Gom-26

In this study, the researcher examined the effect of four nitrogen levels (0, 40, 80 and 120 kg ha^{-1}) and four irrigation levels [0 (no irrigation), 1, 2 and 3] under 0˚C, 1˚C, 2˚C and 3˚C rise in temperature on the production of BARI Gom-26 in Bangladesh. Grain yield of wheat is influenced by the rise of temperature level along with different nitrogen rates (Sen *et al*., 2017). The effect of these two factors on grain yield of wheat is shown in **figure 4**. The yield of wheat grain was in increasing trend with the increase of applied nitrogen rates and was in decreasing trend with the rise of temperature level. Grain yield of wheat usually reaches in steady condition after the application of 150 kg N ha^{-1}. The researcher found highest grain yield at 120 kg N ha^{-1} with 0˚C temperature rise. Grain yield of wheat was lowest at 0 kg N ha^{-1} (control) with 3˚C rise in temperature level.

Regardless of nitrogen level, there was a reduction trend in the grain yield of BARI Gom-26 under different level of temperature rise.



(Source: Sen *et al*., 2017)

Figure 4. Grain yield of wheat (30 years historic weather run) at different nitrogen rates and temperature rise level.

About 8.13%, 16.77% and 24.97% reduction in the grain yield of BARI Gom-26 were observed under 1˚C, 2˚C and 3˚C rise of temperature level, respectively when compared with no rise in the level of temperature. This is because with the rise of temperature level, the losses of soil nitrogen increased through denitrification, volatilization and emission of N_2O. On the other hand, yield of grain and biomass decreased (Kalra *et al*., 2013). Due to the interaction between temperature rise and nitrogen rates, the amount of yield decrease with the rise of temperature level which was higher with increased rate of nitrogen (Sen *et al*., 2017).

Effect of different nitrogen rates and temperature level on NUE in BARI Gom-26

Temperature along with different nitrogen rates influences nitrogen use efficiency (NUE). The effect of different nitrogen rates and rise of temperature level on NUE in wheat is shown in **table 7**. The value of NUE declines with both the rise in temperature level and the rates of nitrogen. NUE value was fluctuated from 17.20 to 29.95 kg grain kg^{-1} N in case of 0˚C temperature rise which indicates the existing atmospheric temperature and the value is in decreasing trend with the increase in nitrogen rates. NUE value is ranged from 12.80 to 25.08 kg grain kg^{-1} N for 1 ˚C rise in temperature level and here the NUE value is also in decreasing trend with the increase in nitrogen rates.

Table 7. Nitrogen use efficiency (kg grain kg^{-1} N) at different N rates and temperature rise level

Nitrogen rates (kg/ha)	Temperature rise level			
	0˚C	1˚C	2˚C	3˚C
40	29.25	25.08	19.58	13.73
80	22.64	16.89	12.48	8.70
120	17.20	12.80	9.68	7.22

(Source: Sen *et al*., 2017)

Similarly in 2˚C and 3˚C rise of temperature level the value of NUE is decreasing with the increase in nitrogen rates where the NUE value is ranged from 9.68 to 19.58 kg grain kg^{-1} N for 2˚C and 7.22 to 13.73 kg grain kg^{-1} N for 3˚C.

From the table 4 it can be concluded that among the twelve NUE values, the highest value (29.95 kg grain kg^{-1} N) was obtained from 40 kg ha^{-1} N rate with no rise in temperature level while the lowest value (7.22 kg grain kg^{-1} N) was observed at 120 kg ha^{-1} N rate with 3˚C rise in temperature level. Because of the reduction in yield with the rise of temperature level the value of NUE was lower in higher temperature level. Again because of higher amount of nitrogen in high nitrogen rates, the value of NUE was lower in high nitrogen rates. Similar type of outcomes were also reported Krupnik *et al*., (2015) who found higher value of NUE in wheat in Bangladesh with lower nitrogen rates. It can be concluded that there was a gradual decrease in NUE with the rise of temperature level (Sen *et al*., 2017).

Improved practices for improving nitrogen use efficiency

Proper nitrogen management system can improve NUE. There are several scientifically available means of nitrogen management to ensure efficient use of agricultural inputs (chemical fertilizers, land, water, and crops). This will enhance beneficial utilization of N in crops and reduce its losses. Nitrogen use efficiency can be improved through the following approaches:

i. Site specific nitrogen management (SSNM)

Site specific nitrogen management (SSNM) includes quantitative knowledge of field specific variability in crops required N and supplying power of expected soil N. The fundamental underlying assumption of this concept is to establish an optimum synchronization between supply and demand of N for plant growth (Giller *et al*., 2004). On the basis of when and what type of decisions are made, SSNM can be grouped in two categories, A) prescriptive SSNM, (2) corrective SSNM (Dobermann *et al*., 2004). In case of prescriptive SSNM before sowing on the basis of soil's N supplying power the amount and time of application are analyzed. On the other hand, in the second diagnostic tools are used to assess nitrogen status of the crop. Example of some promising diagnostic tools for corrective SSNM in cereals are Chlorophyll meters (SPAD), nutrient expert and leaf color charts (LCC). The interpretation of these recorded data is serving as the basis for decisions about timing and quantity of N applications (Schroeder *et al*., 2000).

ii. **Integrated nitrogen management (INM)**

Integrated nitrogen management involves supply of mineralized N from soil organic matter as well as N through chemical fertilizers which are applied externally and their interactions to enhance nitrogen recovery (Olesen *et al*., 2004). This can influence physico-chemical soil environment which will help in better root growth and enhanced supply of other micronutrients (Singh *et al*., 2012).

iii. Slow release fertilizer

Controlled and slow released fertilizer can contribute to increase nitrogen use efficiency to a great extent. There are some slow release fertilizers which are now marketed having the potential to decrease losses of N and improve nitrogen use efficiency (Giller *et al*., 2004). These compounds can reduce N losses by delaying release of nitrogen which may improve the synchronization between crop demand and that of soil N supply. Neem coated urea is an example of slow release nitrogen fertilizers. But, use of these controlled release fertilizer is not so popular yet. Slow release fertilizers contribute only 0.15% of the total N fertilizer consumption. The possible reasons behind this low percentage are high manufacturing cost as well as non- availability by farmers from developing countries (Shivay *et al*., 2001)

iv. Improved method of nitrogen application

Nitrogen use efficiency can be improved through various methods of nitrogen application. Deep placement, foliar spray, placement of urea with mud balls technique in the reduced zone of transplanted puddled rice field can enhance nitrogen recovery percentage through reducing the losses as well as give better crop yield (McBratney *et al*., 2003).

v. Adoption of resource conservation practices

Conservation agriculture (CA):

By practicing conservation agriculture nutrient supply power of soil can be improved. It will ensure better soil health that will lead to higher availability of nutrients to plants (Fageria, 2002). Zero tillage and permanent bed planting with proper residue management can be applied to achieve this (Burgess *et al*., 2002). Physical, chemical and biological properties of soil, aggregate stability (Calvino *et al*., 2003), and change in macro-porosity (Burgess *et al*., 2002) can be improved through conservation agriculture system which will ensure more nutrient availability and better outputs.

Residue management:

Plant growth and development can be influenced by crop residues as they affect the quantity of nutrients available to crops (Mohanty and Mishra, 2014). They are important sources and sinks for carbon and nitrogen cycle (Dinnes *et al*., 2002). Crop residues can supply nitrogen to the plants over long time period by initially converting it into inorganic form and then mineralize it at later stage of crop based on nitrogen demand of crop (Pankhurst *et al*., 2002).

Green manuring:

Legume crops can be used as green manure as they can fix atmospheric free nitrogen in the soil (Vyn *et al*., 2000). These crops help to improve soil health and fertility status, acidification of soil, micro-biological diversity, moisture status of the soil, and thermal regime (Mary and Recous, 1994).

Crop rotation:

Proper crop rotation helps in maintaining the health and fertility of soil as well as nutrient balance. Crop rotations with legume crops help in greater nitrogen availability as well as improve nitrogen use efficiency in cereal crops as legume can fix free atmospheric nitrogen (Gan *et al*. 2003).

vi. Enhancement of nitrogen use efficiency through genetic improvement of crop

Crop improvement through introducing various quality traits which are responsible for effective nitrogen utilization may improve nitrogen use efficiency. With the application of same amount of nitrogen some genotypes may produce different grain yields. Differences in the efficiency of N acquisition may arise from (1) differences in the efficiency of absorption and assimilation of NH_4^+ and other nitrogen species and their regulation (Schmidt *et al*., 2002); (2) the extent and distribution of roots, age of roots, and root induced changes in the rhizosphere affecting mineralization, transformation, and transport of nitrogen (Ladha *et al*., 2003); and (3) root associated biological N fixation (Shrestha and Ladha 1996).

vii. Precision farming

Precision farming is an information and technology based farm input management system which aims at the use of technologies and principles to identify, analyze and manage spatial and temporal variability associated with all aspects of agricultural production within fields for maximum profitability, sustainability, enhancing crop performance, protecting land resources and maintain or improve the environment quality (McBratney *et al*., 2003). Precision farming can be possible through remote sensing, geographic information systems (GIS) and global positioning systems (GPS) technology (Schmidt *et al*., 2002). Application of proper amount of nitrogen in proper place and in right time is very important to improve the use efficiency of nitrogen.

CHAPTER IV

CONCLUSION

Nitrogen use efficiency (NUE) in cereals in Bangladesh specially in rice and wheat is less than 50% of the applied nitrogen. One of the major cause behind this can be the higher susceptibility of applied nitrogen towards different types of losses. However, increase in temperature level can also lower the NUE value which was observed in wheat. Efficiency of using nitrogen can also be varied from variety to variety. For the improvement of the present condition of NUE, use of urea super granule (USG) as a source of nitrogen in stead of prilled urea (PU) can be an effective approach. Besides, site specific nitrogen management, integrated nitrogen management, slow release fertilizer, adoption of different conservation practices, precision farming and crop improvement are necessary for improving the present condition of nitrogen use efficiency in cereal crops in Bangladesh.

CHAPTER V

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