Reduced Dose and Delayed Application of Nitrogen Influence Growth, Yield and Nitrogen Use Efficiency of Transplanted *Aman* Rice Variety BRRI dhan87

A Thesis

By

Student ID: MS-210807

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DEDICATED

TO

MY BELOVED PARENTS

AND BROTHER

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ABSTRACT

The yield potentiality of rice mostly depends on the judicious management and appropriate combination of applied nutrient. The pot experiment was carried out at Professor Purnendu Gain Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna during the monsoon season of 2022. The experiment was conducted to study the influence of reduced dose and delayed application of nitrogen on growth, yield and nitrogen use efficiency of transplanted *Aman* rice variety BRRI dhan87 and to find out the proper nitrogen management schedule for aman season. The experiment was conducted in completely randomized design consisting three nitrogen dose: D_1= 180 urea kg ha^{-1} (Recommended dose), D_2= 162 kg urea ha^{-1} (10% less), D_3= 153 kg urea ha^{-1} (15% less) and three nitrogen application time: T_1= Three split applications at 7, 25, 40 DAT (Recommended), T_2= Three split applications at 7, 35, 50 DAT, T_3= Three split applications at 7, 40, 60 DAT) with three replications. The growth characters like plant height, tiller number, leaf number and SPAD value mostly showed significant impact in case of nitrogen dose rather than nitrogen application time. However the growth characters mostly exhibited non-significant impact due to combined effect of different rate and time of nitrogen application. The performance of the yield parameters (1000 grain weight, grain yield, biological yield and harvest index) was found to be best when treated with 180 kg urea ha^{-1} (D_1) along with application time T_1 (Three split applications at 7, 25, 40 DAT) and T_2 (Three split applications at 7, 35, 50 DAT). Reduction of 10% urea dose from 180 kg urea ha^{-1} to 162 kg urea ha^{-1} did not reduced grain yield significantly. Nitrogen use efficiency (NUE) was the best with 162 kg urea ha^{-1} applied at 7, 35, 50 DAT (T_2D_2) while the performance of 180 kg urea ha^{-1} and 162 kg urea ha^{-1} applied at 7, 25, 40 DAT (T_1) or 7, 35, 50 DAT (T_2) were almost similar. Major yield parameters were showed positive correlation with grain yield.

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CHAPTER I

INTRODUCTION

In Bangladesh, Rice (*Oryza sativa*) is most important food crop, accounting for approximately 75% of total cultivable land (BBS, 2017). Agriculture accounts for 14.74% of GDP and about 41% of the total labor force. Rice is grown on nearly 80% of Bangladesh's arable land, with three cropping seasons: '*Aus*' (March/April to June/July), '*Aman*' (June/July to September/October), and '*Boro*' (November/December to April/May) (BBS, 2016). In the financial year 2018-2019, Total aman rice production was estimated 1,40,54,872 MT with the total area covered by aman rice was estimated 56,21,949 hectares (BBS, 2020). In the financial year 2020-21, total aman rice production increased to 144,37,763 metric tons and total area under aman crop was 56,25,907 hectors (BBS, 2022). Rice is the third largest cereal grain in the world (Rahman *et al.*, 2021), with an estimated global production of 503.17 MT (Mamun *et al.*, 2021). Bangladesh has recently achieved the third position in the world in terms of rice production, surpassing China and India with a volume of 3.6 crore tonnes. China has become the largest producer of rice, accounting for 29.5%, followed by India at 23.8%, Bangladesh at 7.0%, Indonesia at 6.9%, Vietnam at 5.4%, and Thailand at 3.7% (Mamun *et al.*, 2021).

The BRRI (Bangladesh Rice Research Institute) has come up with some really high-yield aman varieties that have become really popular with rice growers in Bangladesh. Recently, these rice varieties (BRRI dhan48, BRRI dhan49, BRRI dhan87 and BRRI dhan92) have been released, and they're helping to increase rice production in the country. In the last few years, the adaption rate of HYVs for Aus, Aman, and Boro season has been really high, 72%, 73% and 98%, respectively (Mamun *et al.*, 2021).

Salinity poses a major threat to coastal agriculture during the dry season, particularly in the southern and southeast regions of the country, where approximately 78,000 hectares of aman rice are cultivated (Shahidullah *et al.*, 2006). The coastal region covers an area of approximately 29,000 square kilometers, or approximately 20% of the entire country. Furthermore, the coastal regions of Bangladesh encompass over 30% of the country's cultivable land. Salinity is a major issue in the coastal areas, affecting approximately 53% of them (Rasel *et al.*, 2013).

Saturated saline soil usually has a pH below 8.3 and it's mostly found in coastal and offshore areas. It's also found in areas that are dry, semi-dry, humid, and arid. The most common salt soils in Bangladesh are in the Khulna and Barisal districts, as well as in areas near Noakhali. Greater Khulna is situated in the AEZ-13 area, which is known as the "Ganges Tidal Floodplain" (Rasel *et al.*, 2013). This issue is exacerbated by a variety of factors, such as temperature and rainfall, topography and crop varieties, as well as a range of socio-economic factors (Shahidullah *et al.*, 2006). Salinity affects crops when they're at their growth stages, which means they don't get nutrient, water etc as much as they should and, in some cases, they don't get at all. Salinity causes unfavorable weather and water conditions that limit the amount of crops that can be grown all year round (Rasel *et al.*, 2013).

Plant nutrients are essential for proper growth and development of crops. Among the major nutrients, Nitrogen (N) is an important plant nutrient that has the potential to increase rice growth and productivity. Nitrogen fertilizer has an effect on rice plant photosynthesis, spikelet formation, biomass accumulation, and effective tillering (Jahan *et al.*, 2022) and also influences root development, water use, and nutrient absorption (Fageria and Santos, 2014). Furthermore, nitrogen can be absorbed by plants in the form of NO_3^- and NH_4^+ ions (Shrestha *et al.*, 2020). Nitrogen deficiency in rice causes old leaves to fall and, in some cases, all leaves to fall, as well as chlorosis at the tip (Chen *et al.*, 2014). Furthermore, nitrogen deficiency in rice plants results in lower grain yields (Zhang *et al.*, 2015).

It is essential to ensure that the time of application of N is appropriate at the critical stage of the rice. Nitrogen dressing at flowering stage increased rice production by 6% and grain protein by 25% (Blumenthal *et al.*, 2008). Rice yield increased because of the extra late application of nitrogen along with two other nitrogen dressings that added up to about 120 kg N ha^{-1} in the farmer's fields (Wopereis, 2002). In transplanting aman season, half of the recommended fertilizer rate is sufficient to optimize production and be economically advantageous for the cultivation of rice cultivars CNI 9012, BINA dhan7, and Aloran (Ahmed *et al.*, 2016). If a farmer cannot afford the expense of fertilizers necessary for high yield, he might be recommended to lower the rate of each required fertilizer by 30% in order to obtain balanced fertilization that provide approximately 80% of the high yield goal (BARC, 2012).

NUE stands for nitrogen use efficiency and it's a widely accepted metric used to evaluate the efficacy of nitrogen (N) management (Congreves *et al.*, 2021). Basically, NUE is the difference between how much nitrogen is used in the production process and how much nitrogen is put into the food system. In other words, nitrogen use is deregulated as the amount of nitrogen used in the products that are harvested divided by the amount of nitrogen that is put into the farm or food system (Silva *et al.*, 2017).

However, globally, N use efficiency has remained below 40% (Omara *et al.*, 2019), meaning that more than 60% of applied N is unused or is lost from soil through de-nitrification, volatilization, surface runoff and leaching from soil-plant systems (Ladha *et al.*, 2005). Different levels of nitrogen fertilizer had a significant impact on rice yield and nitrogen use efficiency (Haque and Haque, 2016). The apparent nitrogen recovery percentage (ANR) and nitrogen utilization efficiency (NUE) decreased as nitrogen level increased up to 120 kg N ha^{-1}. Choosing the right amount of nitrogen fertilizer is really important if you want to get the most out of your crop by reducing the amount of nitrogen you use and making sure you're using as much nitrogen as you can while still maintaining a healthy soil (Baba *et al.*, 2010).

Thus, the timely and balanced application of Nitrogen permits rice to use nitrogen more efficiently throughout the growth season. Improving nitrogen use efficiency is essential to increase agricultural yields, lower production costs, and maintain environmental quality. Appropriate N fertilizer management is crucial for both economic rice production and long-term environmental quality conservation.

Therefore, the present study validated the optimized dose and time of N fertilizer application for better rice production. In these circumstances, the present piece of research work has been formulated with the following objectives:

1. To evaluate the effect of reduced nitrogen dose on growth, yield and nitrogen use efficiency of *T. Aman* rice variety BRRI dhan87 and

2. To determine the effect of delayed nitrogen application on growth, yield and nitrogen use efficiency *T. Aman* rice variety BRRI dhan87.

CHAPTER II

REVIEW OF LITERATURES

A comprehensive review of the literature may help ensure that a credible research question has been addressed and that the proper theoretical paradigm and/or research technique have been chosen. To be more specific, a literature review seeks to locate the present work within the framework of relevant literature while also providing context to the reader. In such circumstances, the review usually comes first, followed by the work's methods and outcomes (Randolph, 2009).

2.1 Worldwide rice production

The United Nations Food and Agriculture Organization (FAO) estimates that more than 50% of the global population subsists on rice as a staple food. The global production of rice, *Oryza sativa L.*, amounts to 510.6 million tonnes (FAO, 2018). With 29.5% of global rice production, China is now the leading producer (Mamun *et al.*, 2021).

To keep pace with population development, the world's rice demand is expected to rise by 25% from 2001 to 2025, making managing rising rice demand sustainably with diminishing natural resources a major problem (Singh *et al.*, 2016). Rice is a major grain crop that feeds 50% of the world's population, particularly in Asian countries such as China (Guo *et al.*, 2019). With a share of 29.5%, China is the world's top producer of rice, followed by India (23.8%) and Bangladesh (7.0%) (Mamun et al., 2021). Despite having only 22% of the world's population and 7% of the world's agricultural area, China is said to consume more than 30% of the world's nitrogen fertilizer (Xie *et al.*, 2002; Peng *et al.*, 2006). When these factors interact, they create another conflict between NUE and rice production, which is critical for agricultural sustainability (Zhang *et al.*, 2015; Xu *et al.*, 2016).

Both Kamiji *et al.* (2011) and Sui *et al.* (2013) found a substantial relationship between crop production and spikelets per unit area, which is influenced by the N supply rate at the panicle stage. Jiang *et al.* (2016) found that appropriate N treatment increased grain production by regulating grain-filling properties.

2.2 Rice production in Bangladesh

Bangladesh is situated in a deltaic region, with a total land area of 147.570 km^2 (Rasel *et al.*, 2013). Approximately 80% of the country is composed of alluvial sediment deposited by the rivers Ganges and Brahmaputra, as well as Tista and Jamuna, as well as the Meghna and its tributaries (Rasel *et al.*, 2013). Our country's agroclimatic conditions are ideal for cultivating rice all year round. Agriculture contributes 10.98% of the national GDP, 5.4% of foreign exchange profits, and 40.6% of total employment (BBS, 2017b, BER, 2015).

Rice production alone amounts to around 4.5 percent of GDP (BBS, 2020). However, the national average rice yield is substantially lower (2.94 t/ha) than the other rice-growing countries (BBS, 2012). With a volume of 3.6 crore tonnes, Bangladesh just surpassed China and India to claim third place in the world for rice production (Mamun *et al.*, 2021).

The arable land of Bangladesh has been rapidly transferred to non-agricultural uses (e.g., 1.07 million hectares of arable land has reduced from 1983 to 2008) (BBS, 2017a). Similarly, projected that an additional 11.8 million tons (44.6 MT) of clean rice must be produced by 2050 compared to the base year (2014) output (32.8 MT) (Kabir *et al.*, 2015).

2.3 Role and effect of nitrogen in rice production

Nitrogen is a fundamental component of all living organisms, as it is present in chlorophyll and nucleic acids. It is also present in amino acids and proteins, and is one of the macronutrients that plants require more than any other nutrient (Zahoor *et al.*, 2014). Plants absorb nitrogen in two distinct forms: Nitrate (NO_3^-) which is absorbed in the dry season and ammonium (NH_4^+) which is absorbed in the rainy season (Abbasi *et al.*, 2017).

Nitrogen plays a critical role in the production of rice, as it is involved in the photosynthesis process, the accumulation of biomass, and the formation of spikelets. As such, it is considered to be the most essential nutrient for the production of rice (Hasegawa *et al.*, 1994; Yoshida *et al.*, 2006). Nitrogen plays a significant role in the development and growth of plants, as well as in their metabolism and allocation of resources. (Ginting *et al.*, 2003; Watts *et al.*, 2010). It increases the plant's height and the amount of tillers it produces. Additionally, nitrogen is a key component of the synthesis of a variety of substances, including enzymes and proteins, hormones and nucleic acids (DNA and RNA) as well as alkaloids and vitamins. (Shrestha *et al.*, 2020).

As a result of nitrogen deficiency, older leaves tend to be shorter, thinner, and more upright than younger leaves, and tend to have a lemon-yellowish and chlorotic tip, as opposed to a greener tip (Shrestha *et al.*, 2020).

2.4 Plant nitrogen concentration at different growth stages of rice

When it comes to rice, there are some really important stages that need to be taken care of. We need to make sure that the crop is getting the nutrients it needs during these critical stages. This stages include emergence, tillering, panicle initiation, booting, heading and maturity. It's important to make sure that these critical stages are taken care of, so that the crop doesn't suffer from nutrient stress (Shrestha *et al.*, 2020).

Application of nitrogen in a timely and distributed manner assists rice in utilizing nitrogen more effectively during the growing season, as it provides the crop with a certain amount of nutrients during the peak growth stages, thus reducing the risk of N losses (Kaushal *et al.*, 2010).

At the farmer level, two N splits are typically applied prior to plantation and tillage in Bangladesh for the purpose of transplanting aman rice (Kaushal *et al.*, 2010). However, three N splits are most suitable for increasing the grain production of existing rice species at mid to high land elevations during the planting and tillage stages, as well as during the panicle initiation stage (Kaushal *et al.*, 2010).

2.5 Rate of nitrogen fertilizer for rice production with major yield contributing character

In Bangladesh, urea is the primary nitrogen source for farmers, accounting for approximately half of the nation's urea requirement of 28 lakh tons. Domestic production of urea is sufficient to meet the 50% of the country's urea requirement, with the remaining 50% having to be imported at exorbitant import prices in foreign currencies (BBS, 2008).

In addition, N has a positive effect on the formation of efficient tillers plants^{-1}, yield and yield characteristics (Islam *et al.* 2008). Application of nitrogen fertilizer to rice plants increases the plant height and the number of panicles (Dobermann and Fairhust, 2000). When treated with nitrogen altered yield characteristics, including total tillers, effective tiller, non-effective tiller, panicle length, spikelet sterility (Islam *et al.*, 2019). Too much N causes fast vegetative growth that causes plant lodging and makes the plant more vulnerable to insects, bugs, and diseases, which lowers production. (Kamruzzaman *et al.*, 2004).

Application of 300 kg N ha^{-1} provided the highest panicle number, dry matter, number of primary branches, total grain and grain yield among the three doses (100, 200, 300 kg N ha^{-1}) (Yoseftabar, 2013).

The nitrogen fertilizer at 150 kg ha^{-1} produced the greatest yield in terms of tillers $hill^{-1}$ (Islam *et al.*, 2008), grains $panicle^{-1}$ and grain yield (Salahuddin *et al.*, 2009), biological yield, and sterile spikelet $panicle^{-1}$ (Islam *et al.*, 2008). When fertilized with 120 kg N ha^{-1}, the maximum grain output of the rice crop was 5.63 tonnes per hectare (Russo, 2012; Kaushal *et al.*, 2010; Baba *et al.*, 2010). On the other hand, the nitrogen fertilizer at 100 kg ha^{-1} produced the highest yield in terms of grain yield, total tillers $hill^{-1}$, and the lowest number of sterile spikes $paneicle^{-1}$ (Islam *et al.*, 2008).

The study conducted by Yoseftabar (2013) revealed significant improvements in plant development, yield characteristics, and grain production when nitrogen was applied at a concentration of 150 kg N ha^{-1}. This resulted in the highest yields of 5.15 Mg ha^{-1} and 6.34 Mg ha^{-1} respectively in BRRI dhan28 and BRRI dhan29 (Khatun, 2015).

Furthermore, when nitrogen was delivered at a rate of 60 kg ha^{-1}, the highest grain yield (5.36 ton ha^{-1}) was found followed by 80 kg N ha^{-1} (4.99 ton ha^{-1}) and the lowest yield (3.29 ton ha^{-1}) was recorded from control treatment (Haque and Haque, 2016). Rony *et al.* (2019) found that nitrogen application at 90 kg ha^{-1} resulted in a maximum plant height and tiller number $hill^{-1}$ among seven nitrogen doses (0 kg N ha^{-1}, 30 kg N ha^{-1}, 60 kg N ha^{-1}, 90 g N ha^{-1}, 120 kg N ha^{-1}, 150 kg N ha^{-1}, 180 kg N ha^{-1}). For BRRI dhan51, the recommended dose among all treatments was 150 kg ha^{-1}. However, a lower dose of 90 kg ha^{-1} produced the greatest yield parameter value.

2.6 Time of Nitrogen application on rice production in relation to major yield contributing components

Studies on rice farming have investigated delayed nitrogen application techniques. The synchronization of nitrogen delivery with the crop's genuine requirement at different growth stages may be one of the factors contributing to the possible advantages reported in delayed nitrogen treatment. The decrease in aman rice production has been attributed to a variety of sources, with inadequate nitrogen fertilizer management being one of the most significant, as N fertilizer can potentially increase rice yield by up to 90% (Win, 2012). This suggests that rice plants require additional nitrogen-based nutrients in order to maximize yield.

According to the results of Moridani *et al.* (2013), splitting application of nitrogen treatment significantly increased the height of rice plants. N_2 (1/3 at 15 DAT + 1/3 at 30 DAT + 1/3 at 45 DAT) was found to be the most effective N fertilizer, producing the longest plants, even though there was no difference in varietal plant height.

Kamruzzaman *et al.* (2013) found that among five nitrogen doses: control (0 kg N ha^{-1}), N_1 (40 kg N ha^{-1}), N_2 (80 kg N ha^{-1}), and N_3 (120 kg N ha^{-1}) and four split levels of N : T1 (⅓ N at basal + ⅓ N at 25 days after transplanting (DAT) + ⅓ N at 50 DAT), T2 (½ N at 25 DAT + ½ N at 50 DAT), T3 (⅓ N at 15 DAT + ⅓ N at 30 DAT + ⅓ N at 45 DAT), T4 [¼ at N 15 DAT + ½ N at 30 DAT + ¼ N at 45 DAT), 120 kg ha^{-1} should be applied in three equal splits viz., ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT provided the higher grain yield for transplanted aman rice variety BRRI dhan30. According to BRRI, recommended dose was 195 kg ha^{-1} for BRRI dhan30 which was much higher than the 120 kg ha^{-1} which means reduced dose and three split or delayed nitrogen application provided higher grain yield.

According to the findings of Shaiful *et al.* (2009), the maximum plant height, the tiller number $hill^{-1}$, the leaves number $hill^{-1}$ and the leaf area $hill^{-1}$, dry matter of root $hill^{-1}$, dry matter of stem $hill^{-1}$, dry matter of leaves $hill^{-1}$, and total dry matter $hill^{-1}$ of the plant were determined from full doze of urea at three equal splits, with 1/3 urea at 15 DAT, 1/3 urea at 30 DAT and 1/3 urea at 55 DAT among the four N level: T_1 (full doze of urea i.e. 215 kg urea ha^{-1} at 15 DAT), T_2 (full doze of urea at two equal splits, ½ at 15 DAT + ½ at 30 DAT), T_3 (full doze of urea at two equal splits, ½ at 15 DAT + ½ at 55 DAT) and T_4 (full doze of urea at three equal splits, 1/3 at 15 DAT

+ 1/3 at 30 DAT + 1/3 at 55 DAT). Delayed nitrogen application with three splits provided the highest result for growth and yield contributing parameter.

2.7 Effect of nitrogen on panicle length and number of spikelets

Three split applications of nitrogen: ½ at basal, ¼ at tillering, and ¼ at panicle initiation yield the longest panicle (Kaushal *et al.*, 2010). Additionally, Ahmed *et al.* (2005) discovered that an increased N dosage resulted in longer panicles.

Yoseftabar (2013) observed that when nitrogen fertilization rose, panicle length also increased. The greatest panicle length was achieved by applying 300 kg N ha^{-1}, whereas the least was recorded when fertilized with 100 kg N ha^{-1}.

Furthermore, Dobermann and Fairhust, (2000) showed that nitrogen fertilizer treatment increases the rice production capacity by continuously increasing the number of spikelets and the number of filled spikelets.

2.8 1000 grain weight with N fertilization

The increase in the rate of nitrogen fertilization from 35 kg to 70 kg nitrogen fed^{-1} has been found to significantly improve the yield of rice straws, grains, and 1000 grain weights (Zaki 2016). This is largely due to the fact that nitrogen is divided into three equal fractions, with one third at transplanting and the other three thirds at tillering and panicle initiation respectively (Raza *et al.*, 2003, Islam *et al.*, 2008 and Hirzel *et al.*, 2011).

The influence of nitrogen on 1000 grain weight have also been conducted by the studies of other authors (Metwally *et al.*, 2010, Ghanbari-Malidareh, 2011 and Sorour *et al.*, 2016). Rony *et al.* (2019) noting a significant relationship between the increase in thousand grain weight and the increase in grain yield, with only a 14% explanation for the difference in grain yield.

2.9 Effect of nitrogen on filled grain panicle^{-1} and unfilled grain panicle^{-1}

According to Ahmed *et al.* (2005), the amount of filled grain panicle^{-1} was dramatically impacted by nitrogen fertilizer. Nitrogen fertilizer @40 kg N ha^{-1} produced the highest filled grains panicle^{-1} among several treatments (Nitrogen levels of 0, 20, 40, 60, and 80 kg ha^{-1}).

Hasanuzzaman *et al.* (2012) noted that the application of urea super granules resulted in the maximum filled grains panicle. When harvested, the use of urea super granules resulted in the highest grain panicle^{-1} of 154.67, grain yield of 9.42 t ha^{-1} and straw yield of 13.33 t ha^{-1}.

2.10 Effect of nitrogen on grain yield and straw yield

Jisan *et al.* (2014) discovered that, among the four varieties (BRRI dhan49, dhan52, dhan56, and dhan57), BRRI dhan52 yielded the greatest grain yield (5.69 t ha^{-1}), followed by BRRI dhan49 (5.15 t ha^{-1}) and BRRI dhan57 yielded the lowest grain yield (4.25 t ha^{-1}). Among the four levels of N, namely 0, 46, 60, and 75 kg ha^{-1}, the crop treated with 75 kg N ha^{-1} exhibited the greatest performance. When fertilized with 75 kg N ha^{-1}, BRRI dhan52 had the greatest results across every parameter evaluated. But 150 kg ha^{-1} was the recommended dose for the variety according to BRRI. So reduced dose of N (75 kg N ha^{-1}) improved yield parameters than the recommended dose for BRRI dhan52.

As per the results of Jahan *et al.* (2022), BRRI dhan58 exhibited a greater responses to a higher N dosage, but BRRI dhan75 had a lesser response among various N doses (0, 25, 50, 75, 100, 125, 150, and 175 kg ha^{-1}). During the Boro season, BRRI dhan58 showed yield increase of up to 348% with 125 kg N ha^{-1}, whereas BRRI dhan75 produced a yield increase of up to 18% with 75 kg N ha^{-1} during the T. *Aman* season. The recommended dose for BRRI dhan75 was 150 kg ha^{-1}, whereas the recommended dose for BRRI dhan58 was 225–300 kg ha^{-1}. The best outcome was obtained for both varieties with a lower nitrogen dosage.

Maximum grain yield of 9.42 t ha^{-1} and straw yield of 13.33 t ha^{-1} were obtained with the application of urea super granules, according to Hasanuzzaman *et al.* (2012) observations. Urea super granules had a grain yield that was about 10% higher than prilled urea.

2.11 Effect of nitrogen on biological yield

Ahmed *et al.* (2005) demonstrated that the biological yields of 40 kg N ha^{-1} and 0 kg N ha^{-1}, respectively, were the greatest and lowest among four levels of nitrogen 0, 20, 40, 60 and 80 kg ha^{-1}.

According to Rony *et al.* (2019), biological yield varied greatly depending on the N dosages. The application of 90 kg N ha^{-1} resulted in the maximum biological production of 9.30 t ha^{-1} among seven doses of nitrogen such as 0 kg N ha^{-1}, 30 kg N ha^{-1}, 60 kg N ha^{-1}, 90 kg N ha^{-1}, 120 kg N ha^{-1}, 150 kg N ha^{-1}, 180 kg N ha^{-1}.

2.12 Nitrogen Use Efficiency (NUE)

NUE is the ratio between the amount of nitrogen used in the manufacturing process and the amount of nitrogen added to the food chain (Silva *et al.*, 2017). Nitrogen use efficiency was calculated by dividing grain yield with amount of nitrogen applied (Merkebu and Amsalu, 2018).

Selecting the appropriate amount of nitrogen fertilizer is a critical factor in achieving the economic benefits of the crop, by decreasing the quantity and increasing NUE (Nitrogen use efficiency) while preserving the ecological health of the crop (Baba *et al.*, 2010). The optimal photosynthesizing activity of the flag leaf is essential for the successful production of rice, as photosynthesis is responsible for 60-90% of the total carbon in the panicle post-heading (Tari *et al.*, 2009). The remaining photosynthesis required for the grain is remobilized from the vegetative organs (Shokri *et al.*, 2009).

The growth, yield and nitrogen use efficiency of rice varieties were significantly affected by the level of nitrogen fertilizer used. The most efficient rice variety in terms of nitrogen use efficiency was BU dhan1, which produced the highest yield and maximum nitrogen use efficiency at the time of application (60 kg N ha^{-1}), as reported by Haque and Haque, (2016). Baba *et al.* (2010) found that the highest NUE was when they treated a rice crop with 120 kg of nitrogen ha^{-1}. The application of nitrogen at 210 kilograms per hectare (kg ha^{-1}) resulted in the highest nitrogen utilization rate and the highest grain yield (Liang *et al.*, 2021).

2.13 Excessive use of nitrogen fertilizer and health hazard

Nitrogen plays a vital role in plant growth and is ubiquitous in all living things. For over half a century, debate has been held on the need to increase the use of nitrogen fertilizers to improve agricultural productivity (Zahoor *et al.*, 2014). However, excessive nitrogen fertilizer application leads to low nitrogen use efficiency and no increase in yield. NUE ranges from 30-50% for the majority of plant species. The remainder of nitrogen is absorbed by soil microorganisms, lost through leaching, or converted into nitrous oxide (Wuebbles, 2009; Ng *et al.*, 2016). This has led to significant environmental problems like soil acidification; air pollution; water erosion (Smil, 1999; Ruiz *et al.*, 2008; Guo *et al.*, 2010).

The accumulation of nitrogen (N) in surface water and groundwater, as well as nitrate pollution, has a detrimental effect on natural ecosystems. This has the potential to alter biodiversity and lead to the production of greenhouse gases (CO_2, CH_4, N_2O etc) (Ward, 2009).

Additionally, the presence of excess nitrogen in the water can lead to the growth of algae in coastal areas and in freshwater lakes, thus reducing the oxygen supply to the species that rely on it (Ward, 2009). Furthermore, nitrate contamination of groundwater or consumption of nitrate-rich plants can lead to severe pathological health problems in humans (Ward, 2009; Ward *et al.*, 2005). Efficient nitrogen use can not only reduce agricultural production costs, but can also reduce environmental pollution. Therefore, by utilizing the correct amount of nitrogen, we may be able to achieve cost savings while preserving the environment (Islam *et al.*, 2019).

Based on the researches reviewed above, it can be concluded that nitrogen rate, nitrogen application time and their combination have a significant impact on rice growth, yield and yield contributing characteristics as well as nitrogen use efficiency (NUE). For boosting the rice crop's growth parameter (plant height, tiller number, leaf number) and yield component (effective tiller hill^{-1}, grain yield, straw yield, biological yield), three N splits are best. Nitrogen dose @40-300 kg ha^{-1} was shown to have a significant impact on yield and yield contributing features in the majority of studies. The current study was therefore required in order to ascertain the influence of varying nitrogen treatment times and rates on growth, yield and nitrogen use efficiency (NUE) of rice.

CHAPTER III

MATERIALS AND METHOD

This chapter provides a brief description of the materials and methods employed in the pot experiment to evaluate the effects of reduced and delayed application of nitrogen on growth and yield of HYV *T. Aman* rice variety BRRI dhan87. It also covers the location of the experiment, the weather and climatic conditions, the soil characteristics, the materials used, the experimental design, the treatment, the cultural operations, the land preparation, the manuring and fertilization, the intercultural operations, the harvesting, the data collection procedure, and the statistical analysis of the collected data. The specific processes or approaches employed in the experiment were designed to identify, select, process and evaluate information related to the issue, with robust research objectives to guide the research effort, including data collection and analysis.

3. Description of the experimental procedure

3.1 Experimental site

The pot experiment was conducted at Professor Purnendu Gain Field Laboratory of the Agrotechnology Discipline of Khulna University in Khulna. The pot experiment was conducted under semi-controlled condition. The site of the experiment was situated in Agro-ecological zone 13, which is composed of salt-based, non-calcium-based and acid-based soils and is part of the Gangetic tidal floodplain. The geographical location of the site is 22°47" N and 89°34" E, with a subtropical climate.

3.2 Period of experiment

The experiment was carried out during aman season (July-December). Transplanting of seedlings was done on August 8, 2022 and harvesting was done on November 17, 2022.

3.3 Soil

The experiment soil used in the pot was clay soil in texture and the pH level of soil was 6.7 which means the soil was neutral. The electrical conductivity (EC) of the soil was 0.34 dS m^{-1} i.e. non-saline. The soil analysis was carried out at laboratory of Soil, Water and Environment Discipline of Khulna University.

Details of the soil test analysis result are given below:

Characteristics	Soil test value	Status
Soil pH	6.7	Neutral
Electrical conductivity (EC) ($dS\ m^{-1}$)	0.34	Non-saline
Total nitrogen (%)	0.238	High
Total phosphorus (%)	0.0029	Low
Total potassium (%)	0.745	High
Zinc (ppm)	4.45	Low-medium

3.4 Climate

The experimental site was situated 2–3 meters above the mean sea level, within the agro ecological zone of the Ganges River Floodplain. The climate of the area is subtropical, with the average annual rainfall amounting to 1800 mm, the majority (80%) of which falls during the peak of the rainy season (June-August). This climate is conducive to the cultivation of Aman rice, which is one of the most popular crops in Bangladesh.

3.5 Plant materials

BRRI dhan87 a high yielding rice variety, developed by the Bangladesh Rice Research Institute in 2018, has an average height of 122 cm and is characterized by strong stems, light green leaves, and long and thin rhizomes. Each 1000 grams of nutritious rice weigh approximately 24.1 grams and the amylose of the rice is 27%. This variety has a life span of 125-128 days and is capable of yielding an average of 6.5 tonnes per hectare. It is recommended to sow seed between 15 June and 7 July, and seedlings aged 25-30 days should be transplanted between 7th July and 15th August. According to BBRI's recommendation, harvesting should take place between 25 October and 15 November.

The seeds of BRRI dhan87 were collected from Bangladesh Agricultural Development Corporation (BADC) regional station, Fultola, Khulna.

3.6 Preparation of pot

In order to prepare the final pot, the soil was first collected from the experimental site. Subsequently, the soil was processed in order to facilitate the removal of debris, insect larvae, weeds, compacted soil breaks, soil leveling, soil structure improvement, etc. Weed, stubble, and residue from the previous harvest were removed. The pot was then filled with the freshly cleaned soil. The weight of each pot was 300 g and soil weight was 10.5 kg. All basal dose of fertilizers were applied to the soil of the pot and mixed thoroughly. Adequate water was added to the soil to make it a wet condition.

3.7 Experimental treatments and design

The experiment was conducted with Completely Randomized Design (CRD) with three replications. The experiment consisted of two factors such as:

A. Nitrogen (urea) dose
B. Nitrogen (urea) application time

Factors	Symbol	Description
Factor A:	D_1	180 kg urea ha^{-1} (Recommended dose)
Nitrogen (urea) dose	D_2	162 kg urea ha^{-1} (10% less)
	D_3	153 kg urea ha^{-1} (15% less)
Factor B:	T_1	Three split application at 7, 25, 40 days after transplanting (DAT) (Recommended)
Nitrogen (urea) application time	T_2	Three split application at 7, 35, 50 DAT
	T_3	Three split application at 7, 40, 60 DAT

Treatment combination among the nitrogen (urea) application rates and application times:

T_1D_1= 180 kg urea ha^{-1} at three split applications such as 7, 25, 40 DAT

T_1D_2= 162 kg urea ha^{-1} at three split applications such as 7, 25, 40 DAT

T_1D_3= 153 kg urea ha^{-1} at three split applications such as 7, 25, 40 DAT

T_2D_1= 180kg urea ha^{-1} at three split applications such as 7, 35, 50 DAT

T_2D_2= 162 kg urea ha^{-1} at three split applications such as 7, 35, 50 DAT

T_2D_3= 153 kg urea ha^{-1} at three split applications such as 7, 35, 50 DAT

T_3D_1= 180kg urea ha^{-1} at three split application such as 7, 40, 60 DAT

T_3D_2= 162 kg urea ha^{-1} at three split application such as 7, 40, 60 DAT

T_3D_3= 153 kg urea ha^{-1} at three split application such as 7, 40, 60 DAT

3.8 Fertilizer application

In accordance with the BRRI recommendation, fertilizer doses were administered during the final pot preparation.

S/N	Fertilizer	Rate of application(kg ha^{-1})
1	TSP	60
2	MoP	105
3	Gypsum	68

The experimental pots were fertilized according to BRRI's recommendations, with TSP (Triple Super Phosphate), MoP (Muriate of Potash) and Gypsum which were applied to each pot during final pot preparation. Urea was applied as per treatment schedule. The source of nitrogen, phosphorus, potassium, and sulfur was determined by the application of urea, TSP, MoP and gypsum to the experimental pots in accordance with BRRI dhan87's recommendations.

Accordingly, each pot received 0.3 g TSP, 0.53 g MoP and 0.34 g gypsum, respectively. All fertilizers, except urea, were applied at the time of final pot preparation.

3.9 Transplanting of seedlings

Twenty three days old seedlings were uprooted and then planted in the prepared pot. Two to three seedlings were transplanted in each pot. The transplantation was scheduled at August 8, 2022.

3.10 Care after transplanted seedling

Following transplantation, the pot was left in a shaded location for a period of 10 days in order to ensure that the seedlings were able to settle into their new environment. A light water level was maintained to the pots. Mortile seedings were replaced by new fresh seedings.

3.11 Intercultural operations

3.11.1 Irrigation

The experimental pots were maintained standing water by giving light irrigation time to time throughout the vegetative and reproductive stages. Watering was reduced at ripening stage and irrigation was stopped 10 days before harvest.

3.11.2 Plant protection

The primary harmful pest to the rice plants was the Green Leaf Hopper (GLH). To control the GLH, nitro 505 EC (chloropyrifos+cypryrmethrin) was applied at a concentration of 1 ml/L at 11 days after transplanting.

3.12 Harvesting and postharvest operations

Once 80-90% of the grains had achieved a golden yellow color, the crop was harvested. The harvest took place on November 17, 2022 and the crop was threshed manually following the harvest. The grain was cleaned and dried to a low moisture content and the straw was also dried properly. Grain and straw weight of each pot was measured with a digital balance and the data were recorded properly.

3.13 Data collection, recording and calculation

The data on plant and growth parameters like plant height, tiller number $hill^{-1}$, leaf number $hill^{-1}$, SPAD value were collected from each pot at 30 DAT (days after transplanting), 45 DAT, 60 DAT, 75 DAT, 90 DAT and at harvest. Data on yield contributing parameters such as effective tiller $hill^{-1}$, panicle length, filled grain $panicle^{-1}$, unfilled grain $panicle^{-1}$, grain yield, straw yield, biological yield and harvest index were also collected from the experimental rice plant.

3.13.1. Plant and growth parameter measurement procedure

3.13.1.1 Plant height (cm)

The plant height was measured six times over a fifteen-day period, beginning from 30 DAT and ended at harvest. The height of plant was recorded in centimeter (cm) scale at the time of 30 DAT (days after transplanting), 45 DAT, 60 DAT, 75 DAT, 90 DAT and at harvest from each pot. The height was measured from the ground level to the tip of the hill.

3.13.1.2 Number of tiller $hill^{-1}$

The number of tiller $hill^{-1}$ of the plant was measured six times over a period of 15 days, starting at 30 DAT and ending at harvest. The number of tiller $hill^{-1}$ was recorded 5 times at the time of 30 DAT, 45 DAT, 60 DAT, 75 DAT, 90 DAT and at harvest from each pot.

3.13.1.3 Leaf number $hill^{-1}$

The number of leaf was recorded five times at 30 DAT, 45 DAT, 60 DAT, 75 DAT and 90 DAT from each pot.

3.13.1.4 SPAD (Soil Plant Analysis Development) value/ Leaf chlorophyll

The SPAD value was recorded with a SPAD meter. The Chlorophyll Meter SPAD-502Plus was made in Japan. It is a hand-held device that is widely used for the rapid, accurate and non-destructive measurement of leaf chlorophyll concentrations without any damage to the plant. The meter basically exposes a little area of the leaf to significant amounts of light and calculates the amount that chlorophyll was unable to absorb throughout the photosynthetic process. Since nitrogen is a component of chlorophyll, one may determine the quantity of nitrogen in a plant indirectly by measuring chlorophyll. It was recorded at 30 DAT, 45 DAT, 60 DAT, 75 DAT and

90 DAT from each pot. Firstly, the SPAD value of two leaves were measured from each pot then average value were calculated.

3.13.2 Yield contributing parameters measurement procedure

3.13.2.1 Effective tiller hill^{-1}

Grain bearing panicle is called effective tiller. After harvesting, total number of effective tiller hill^{-1} was counted.

3.13.2.2 Panicle length (cm)

After collecting all the panicles, length was measured separately and average panicle length was measured for each pot.

3.13.2.3 Filled grain panicle^{-1}

The total number of filled grains of each panicle of the hill was counted and the average number of filled grain panicle^{-1} was recorded.

3.13.2.4 Unfilled grain panicle^{-1}

The total number of unfilled grains of each panicle of the hill was counted and the average number of unfilled grain panicle^{-1} was recorded.

3.13.2.5 1000 grain weight (g)

All grains were counted from each individual pot, then weighed in grams by electric balance and then converted the data into 1000 seed weight and recorded.

3.13.3 Yield parameters measurement procedure

3.13.3.1 Grain yield (g hill^{-1})

The grains from each treatment pot were sun dried well and carefully weighed. The weight of grain from each pot was recorded as g hill^{-1}.

3.13.3.2 Straw yield (g hill^{-1})

Total straw of each pot was sun dried well and weighed carefully and recorded as g hill^{-1}.

3.13.3.3 Biological yield (g $hill^{-1}$)

All grain yields and straw yields were considered to be biological yield. The biological yield was calculated with the following formula and recorded as g $hill^{-1}$.

$$\textbf{Biological yield} = \textbf{Grain yield} + \textbf{Straw yield}$$

3.13.3.4 Harvest index (%)

The percentage of the grain that are harvested is called the harvest index and it's determined by comparing the economic yield to the biological yield. The harvest index is calculated using this formula:

$$\textbf{Harvest index} = \frac{\textbf{Economic Yield}}{\textbf{Biological Yield}} \times 100$$

3.13.4 Nitrogen use efficiency (NUE)

Nitrogen use efficiency was calculated after obtaining the grain yield. The nitrogen use efficiency was determined by dividing the grain yield by the amount of nitrogen applied to the plant.

$$\text{N use efficiency (NUE)} = \frac{\text{Grain yield}}{\text{N supply}}$$

3.14 Statistical analysis of data

In order to assess the numerical data pertaining to the growth and yield performance of BRRI dhan87, ANOVA (analyses of variance) was performed to analyze the effects of two factors and their interactions using the Statistix 10.0 software. The significance of the difference between the treatments means of two pairs of characters was then evaluated using the Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The goal of the experiment was to evaluate how reduced and delayed nitrogen application affected growth, yield and nitrogen use efficiency of BRRI dhan87 rice variety. Significant interactions between the rate and time of nitrogen treatment were detected on crop growth characters, yield contributing characters, and yield parameters. The effects of individual treatments, as well as their interactions, on all of the analyzed parameters, have been presented in this chapter.

4.1 Plant and growth parameters

4.1.1 Plant height

4.1.1.1 Effect of different time of nitrogen application

Nitrogen application at 30 and 45 DAT (days after transplanting) had a significant ($p<0.05$ and $p<0.01$, respectively) effect on plant height but at 60, 75, 90 DAT and at harvest had no significant effect on plant height (Table 1). At 30 DAT, the maximum (59.00 cm) plant height was found in T_1 (Three split applications at 7, 25, 40 DAT) and the minimum (55.88 cm) height was found in T_2 (Three split applications at 7, 35, 50 DAT). At 45 DAT, the maximum (80.59 cm) plant height was found in T_2 (Three split applications at 7, 35, 50 DAT) and the minimum (74.23 cm) height was found in T_1 (Three split applications at 7, 25, 40 DAT) which was statistically similar to the plant height (74.67 cm) of T_3 (Three split application at 7, 40, 60 DAT). The effect of various time of nitrogen application did not affect the plant height at 60 DAT, 75 DAT, 90 DAT and at harvest (Table 1). Delayed application of N affected the tiller number at early stage which was minimized at later stages.

Table 1. Effect of different time of nitrogen application on plant height of BRRI dhan87 rice at different DAT

Time	Plant height(cm)					
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
T_1	59.00 a	74.23 b	98.00	103.72	108.89	115.67
T_2	55.88 b	80.59 a	96.78	103.44	111.56	114.33
T_3	57.27 ab	74.67 b	96.83	105.78	110.00	113.89
LS	*	**	**NS**	**NS**	**NS**	**NS**
CV (%)	**3.91**	**3.44**	**2.81**	**2.34**	**1.98**	**1.67**

Figure in a column having similar letter meant statistically similar while dissimilar letter meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3=Three split nitrogen applications at 7, 40, 60 DAT.

4.1.1.2 Effect of different dose of nitrogen application

Different dose of nitrogen had significant ($p<0.05$) effect on plant height at 30 DAT, 60 DAT and highly significant ($p<0.01$) effect at harvest but had no significant effect at 45 DAT, 75DAT and 90 DAT (Table 2). At 30 DAT, the maximum height (59.22 cm) of the plant was observed from D_2 (162 kg urea ha^{-1}) which was at par with D_1 (180 kg urea ha^{-1}) and the minimum height (55.94 cm) was observed from D_3 (153 kg urea ha^{-1}). At 60 DAT, the highest plant height (99.44 cm) was observed from D_1 (180 kg urea ha^{-1}) and the lowest plant height (95.17 cm) was observed from D_3 (153 kg urea ha^{-1}). At the time of harvest, D_1 (180 kg urea ha^{-1}) provided the highest plant height (119.22 cm) where D_3 (153 kg urea ha^{-1}) provided the lowest plant height (112.22 cm) which was statistically similar to the plant height (112.44 cm) of D_2 (162 kg urea ha^{-1}) (Table 2). In most of the cases higher plant height was observed in D_1 (Recommended dose) because plant height was enhanced with higher dose of urea.

Table 2. Effect of different dose of nitrogen application on plant height of BRRI dhan87 rice at different DAT

Dose	Plant height(cm)					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
D_1	57.00 ab	77.42	99.44 a	105.11	111.44	119.22 a
D_2	59.22 a	75.92	97.00 ab	104.33	109.00	112.44 b
D_3	55.94 b	76.14	95.17 b	103.50	110.00	112.22 b
LS	*	**NS**	*	**NS**	**NS**	**
CV (%)	**3.91**	**3.44**	**2.81**	**2.34**	**1.98**	**1.67**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.1.3 Interaction effect of different dose and time of nitrogen application

Interaction effect of different time and rate of nitrogen application had significant ($p<0.05$) effect on plant height at harvest. There was no statistically significant variation in plant height of rice at other stages as 30 DAT, 45 DAT, 60 DAT, 75 DAT and 90 DAT (Table 3). At the time of harvest, T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) provided the highest plant height (121.33 cm) and T_1D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) provided the lowest plant height (111.00 cm) which was statistically similar to T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) and T_3D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT). Proper nitrogen management is very important to increase rice growth parameters and yield contributing characters (Xu *et al.*, 2012). The findings of Zeng *et al.* (2015) showed that timing and dose of nitrogen application had significant impact on rice cultivation. Nitrogen was used at a rate of 90 kg $hectare^{-1}$ caused the maximum plant height and the tiller number $hill^{-1}$, stated by Rony *et al.* (2019). The rise in plant height following the application of nitrogen fertilizers is likely to be attributed to the increased availability of nitrogen, which increased the leaf area leading to an increase in photo assimilates resulting in an increase in the amount of dry matter (Chaturvedi, 2005). Nitrogen contributed to the increase in cell number and cell elongation that is why plant height was increased. The height of the plant increases with the application of nitrogen up to a certain limit, which is similar to the findings of Talukder, (1973).

Table 3. Interaction effect of different dose and time of nitrogen application on plant height of BRRI dhan87 rice at different DAT

Interaction		Plant height (cm)					
Time	**Dose**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
T_1	D_1	59.67	76.60	100.67	105.00	109.33	121.33 a
	D_2	60. 50	73.50	98.33	102.00	108.00	114.67 b-d
	D_3	56.83	72.60	95.00	104.17	109.33	111.00 d
T_2	D_1	54.83	79.83	98.00	103.33	115.00	119.00 ab
	D_2	57.83	80.44	96.00	105.33	110.00	111.33 d
	D_3	55.00	81.48	96.33	101.67	109.67	112.67 cd
T_3	D_1	56.50	75.83	99.67	107.00	110.00	117.33 a-c
	D_2	57.83	73.83	96.67	105.67	109.00	111.33 d
	D_3	56.00	74.33	94.17	104.67	111.00	113.00 cd
LS		**NS**	**NS**	**NS**	**NS**	**NS**	*
CV (%)		**3.91**	**3.44**	**2.81**	**2.34**	**1.98**	**1.67**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.2 Tiller number

4.1.2.1 Effect of different time of nitrogen application

The application of nitrogen at different times had a variable impact on the number of rice tiller. The effect on the tiller number was statistically highly significant ($p<0.01$) at 30 DAT and 45 DAT, but was not statistically significant at 60 DAT, 75 DAT, 90 DAT and at harvest. The highest tiller number (23.00 cm) was observed at T_1 (Three split nitrogen applications at 7, 25, 40

DAT) and the lowest (19.56 cm) was observed at T_2 (Three split nitrogen applications at 7, 35, 50 DAT) which were statistically similar to the value (19.89 cm) at T_3 (Three split nitrogen applications at 7, 40, 60 DAT) for 30 DAT. At 45 DAT, highest tiller number (23.22 cm) was observed at T_1 (Three split nitrogen applications at 7, 25, 40 DAT) and the lowest (21.11 cm) was observed at T_3 (Three split nitrogen applications at 7, 40, 60 DAT). In most of the cases, T_1 (Recommended time) produced the highest tiller number (Table 4).

Table 4. Effect of different time of nitrogen application on tiller number of BRRI dhan87 rice at different DAT

Time	Tiller number (cm)					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
T_1	23.00a	23.22a	16.00	14.56	13.67	12.44
T_2	19.56b	22.00ab	16.78	15.22	13.78	12.00
T_3	19.89b	21.11b	14.78	14.11	13.44	12.33
LS	**	**	NS	NS	NS	NS
CV (%)	**6.20**	**5.57**	**11.06**	**8.00**	**6.62**	**5.68**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.1.2.2 Effect of different dose of nitrogen application

Various rate of nitrogen application had highly significant ($p<0.01$) effect on tiller number at 30 DAT, 45 DAT and had significant ($p<0.05$) effect at the time of harvest. On the other side, 60 DAT, 75 DAT and 90 DAT provides non-significant effect due to various doses of nitrogen application. At 30 DAT, the highest tiller number was resulted from D_1 (180 kg urea ha^{-1}) treatment with 23.00 cm and the lowest (19.22 cm) was resulted from D_3 (153 kg urea ha^{-1}) treatment. At 45 DAT, the highest tiller number was resulted from D_1 (180 kg urea ha^{-1})

treatment with 23.22 cm and the lowest (20.89 cm) was resulted from D_3 (153 kg urea ha^{-1}) treatment. At the time of harvest, D_1 (180 kg urea ha^{-1}) provided highest result (12.78 cm) which was statistically similar with D_2 and D_3 showed the lowest result (11.89 cm) (Table 5).

Table 5. Effect of different dose of nitrogen application on plant tiller number of BRRI dhan87 rice at different DAT

Dose	Tiller number (cm)					
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
D_1	23.00a	23.22a	16.89	15.33	13.67	12.78a
D_2	20.22b	22.22ab	15.11	14.00	13.33	12.00ab
D_3	19.22b	20.89b	15.56	14.56	13.89	11.89b
LS	**	**	**NS**	**NS**	**NS**	*
CV (%)	**6.20**	**5.57**	**11.06**	**8.00**	**6.62**	**5.68**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.2.3 Interaction effect of different dose and time of nitrogen application

The interaction was statistically highly significant ($p<0.01$) at 30 DAT, 45 DAT and did not have a significant impact on rice at various days after transplanting (60 DAT, 75 DAT, 90 DAT and at harvest). At 30 DAT, T_1D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 25 and 40 DAT) with 23.67 cm provided the highest result following T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25 and 40 DAT) treatment with 23.33 cm and T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35 and 50 DAT) treatment with 23.00 cm and the lowest result was obtained from T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35 and 50 DAT) following T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) with 16.67 cm. At 45 DAT, the maximum number of tiller reaching 24.67 cm at the T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35 and 50 DAT) and the lowest tiller number (19.67 cm) of rice was owed to the T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT). The tiller number remained statistically similar at 60 DAT, 75 DAT, 90 DAT and at harvest. This suggests that the tiller numbers did not increase or decrease significantly as a result of the interaction of the different rates and timing of the urea application. In the opinion of Singh and Singh, (2002), the rise in nitrogen levels led to a significant rise in the total tillers hill^{-1} up to a specific stage. Increased N rates and higher seedling density, as reported by Ahmad *et al.* (2005), increased the number of tillers that directly affect rice grain production. The importance of nitrogen in improving fertile tillers, kernel weight, number of kernels per panicle, and harvest index is highlighted by different authors (Ahmad *et al.*, 2005; Manzoor *et al.*, 2006; Rajarathinam and Balasabramaniyan, 1999; Lin *et al.*, 2009).

Table 6. Interaction effect of different dose and time of nitrogen application on tiller number of BRRI dhan87 rice at different DAT

Interaction		Tiller number (cm)					
Time	**Dose**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
T_1	D_1	23.33a	24.00ab	16.33	15.00	13.67	12.67
	D_2	23.67a	24.00ab	15.67	13.67	13.00	12.33
	D_3	22.00ab	21.67abc	16.00	15.00	14.33	12.33
T_2	D_1	23.00a	24.67a	19.67	16.67	14.00	12.67
	D_2	16.67c	20.00c	15.33	14.67	13.67	11.67
	D_3	19.00bc	21.33abc	15.33	14.33	13.67	11.67
T_3	D_1	22.67ab	21.00bc	14.67	14.33	13.33	13.00
	D_2	20.33abc	22.67abc	14.33	13.67	13.33	12.00
	D_3	16.67c	19.67c	15.33	14.33	13.67	11.67
LS		**	**	**NS**	**NS**	**NS**	**NS**
CV (%)		**6.20**	**5.57**	**11.06**	**8.00**	**6.62**	**5.68**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1%

level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.3 SPAD (Soil Plant Analysis Development) value of leaf

4.1.3.1 Effect of different time of nitrogen application

The time of nitrogen application had a range of effects on the SPAD values of rice at various days after transplanting like 30 DAT, 45 DAT, 60 DAT, 75 DAT and 90 DAT. The SPAD values of 45 DAT and 60 DAT showed a statistically highly significant ($p<0.01$) effect on rice. On the other hand, the values of 30 DAT, 75 DAT and 90 DAT demonstrated a statistically significant ($p<0.05$) impact on SPAD value. At 30 DAT, the highest SPAD value (36.52) was observed from T_1 (Three split nitrogen applications at 7, 25, 40 DAT) which was statistically significant to T_3 (Three split nitrogen applications at 7, 40, 60 DAT) and the lowest SPAD value (34.31) was observed from T_2 (Three split nitrogen applications at 7, 35, 50 DAT). Both T_1 (Three split nitrogen applications at 7, 25, 40 DAT) and T_3 (Three split nitrogen applications of 7, 40 and 60 DAT) showed statistically similar and lowest SPAD values (35.29) at 45 DAT, while T_2 showed the highest SPAD value (39.69). The SPAD value at 60 DAT was the highest (37.26) at T_2 (three split nitrogen applications at 7 DAT, 35 DAT and 50 DAT) which was statistically consistent with T_3 (Three split nitrogen applications of 7, 40 and 60 DAT) and the lowest (33.23) was observed at T_1 (Three split nitrogen applications of 7, 25 and 40 DAT). In case of 75 DAT, the highest SPAD value (35.63) was observed from T_2 (Three split nitrogen applications at 7, 35, 50 DAT) and the lowest SPAD value (32.56) was observed from T_1 (Three split nitrogen applications at 7, 25, 40 DAT). Finally at 90 DAT, the highest SPAD value (32.87) was observed from T_2 (Three split nitrogen applications at 7, 35, 50 DAT) and the lowest SPAD value (30.14) was observed from T_1 (Three split nitrogen applications at 7, 25, 40 DAT) (Table 7).

Table 7. Effect of different time of nitrogen application on SPAD value of BRRI dhan87 rice at different DAT

Time	SPAD value				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	36.52a	35.29b	33.23b	32.56b	30.14b
T_2	34.31b	39.69a	37.26a	35.63a	32.87a
T_3	34.93ab	35.29b	35.44a	33.82ab	32.30a
LS	*	**	**	*	*
CV (%)	**4.86**	**6.61**	**6.24**	**5.57**	**5.80**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.1.3.2 Effect of different dose of nitrogen application

The effects of different doses of nitrogen-containing nitrogen application on SPAD values of rice at various days following transplantation (Table 8) were not statistically significant (30 DAT, 45 DAT, 60 DAT, 75 DAT, 90 DAT). Consequently, SPAD values for rice did not significantly increase or decrease at various days post-transplantation due to the different treatments (D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}) (Table 8).

Table 8. Effect of different dose of nitrogen application on SPAD value of BRRI dhan87 rice at different DAT

Dose	SPAD value				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
D_1	35.15	36.80	34.50	34.11	31.76
D_2	35.14	36.99	36.34	33.87	31.87
D_3	35.47	36.96	35.09	34.03	31.68
LS	NS	NS	NS	NS	NS
CV (%)	4.86	6.61	6.24	5.57	5.80

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.3.3 Interaction effect of different dose and time of nitrogen application

Due to the interaction effect of different rate and time of nitrogen application, there was no statistically significant effect on SPAD value of rice at different days after transplanting such as 30 DAT, 45 DAT, 60 DAT, 75 DAT and 90 DAT. This implies that all treatments result in nearly similar SPAD values for the various days after transplantation of rice (Table 9). The SPAD values of rice were significantly influenced by the variety of the rice, the stage of growth of the leaves, the leaf position, and the measurement point of a leaf blade (Lin *et al.*, 2010). The application rate of urea N (180 kg ha^{-1}) could significantly increase the rate of N utilization of plants (stem sheath, leaf, and ear) and enable functional leaves of the rice to have a high degree of light capture and photochemical efficiency in the heading and flowering periods, thus increasing the yield of the rice (Fu *et al.*, 2021). According to Hassan et al. (2009), the physiological nitrogen demand of the crop at each development stage influences the SPAD reading, which indicates the plant nitrogen status and the amount of nitrogen to be administered. Yoseftabar et al. (2012) found that the interaction of nitrogen rate and split application of nitrogen fertilizer had no significant impact on SPAD values of hybrid rice.

Table 9. Interaction effect of different dose and time of nitrogen application on SPAD value of BRRI dhan87 rice at different DAT

Interaction		SPAD value				
Time	**Dose**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
T_1	D_1	36.95	36.68	32.57	33.38	30.49
	D_2	35.30	33.95	34.55	32.12	30.20
	D_3	37.30	35.25	32.57	32.18	29.73
T_2	D_1	34.95	39.45	35.97	34.82	32.65
	D_2	33.45	39.27	38.58	36.45	33.38
	D_3	34.53	40.37	37.23	35.63	32.59
T_3	D_1	33.55	34.27	34.97	34.13	32.16
	D_2	36.67	37.77	35.88	33.05	37.03
	D_3	34.57	35.25	35.47	34.27	32.72
LS		**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)		**4.86**	**6.61**	**6.24**	**5.57**	**5.80**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.4 Leaf number

4.1.4.1 Effect of different time of nitrogen application on leaf number

The various time of nitrogen application had a highly significant ($p<0.01$) effect on rice leaf number at 30 DAT and 45 DAT. There were no significant differences in rice leaf number at 60, 75 and 90 DAT, as a result of variations in nitrogen application times. At 30 DAT, T_1 (Three split nitrogen applications at 7, 25 and 40 DAT) achieved the highest value (72.11), while T_3

(Three split nitrogen applications at 7, 40, 60 DAT) achieved the lowest value (62.89) which was statistically similar to T_2 (Three split nitrogen applications at 7, 35, 40 DAT) with 63.11 value. At 45 DAT, the highest value (83.11) was achieved at T_1 (Three split nitrogen applications at 7, 25, 40 DAT), whereas the lowest value (71.89) was achieved at T_3 (Three split nitrogen applications at 7, 40, 60 DAT). The rice leaf number remains similar at 60 DAT, 75 DAT and 90 DAT respectively, due to differences in the application time of nitrogen (Table 10).

Table 10. Effect of different time of nitrogen application on leaf number of BRRI dhan87 rice at different DAT

Time	Leaf number hill^{-1}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	72.11a	83.11a	67.56	62.00	60.22
T_2	63.11b	79.78a	64.56	59.78	57.22
T_3	62.89b	71.89b	64.33	61.33	59.56
LS	**	**	**NS**	**NS**	**NS**
CV (%)	**6.87**	**8.09**	**11.18**	**9.60**	**11.81**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.1.4.2 Effect of different dose of nitrogen application

The effects of leaf number of rice were demonstrated across a variety of treatments (D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}). Different dose of nitrogen on leaf number of rice showed highly significant (*$p<0.01$*) effect at 45 DAT, 75 DAT, 90 DAT and had no statistically significant effect at 30 DAT and 60 DAT. At 45 DAT, D_1 (180 kg urea ha^{-1}) provided the highest leaf number (91.56) and D_3 (153 kg urea ha^{-1}) provided the lowest value (63.78). At 75 DAT, the highest leaf number was obtained from D_1 (180 kg urea ha^{-1}) with 67.22

which was statistically similar to D_2 (162 kg urea ha^{-1}) with 62.33 and lowest was observed from D_3 (153 kg urea ha^{-1}) with 53.56. At 90 DAT, the highest leaf number (64.56) was obtained from D_1 (180 kg urea ha^{-1}) and the lowest (52.22) was obtained from D_3 (153 kg urea ha^{-1}) (Table 11). Applying recommended dose of N fertilizer resulted in an increase in the number of leaves. But the 10% reduced dose of N also provided the similar result as the recommended dose.

Table 11. Effect of different dose of nitrogen application on leaf number of BRRI dhan87 rice at different DAT

Dose	Leaf number $hill^{-1}$				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
D_1	67.67	91.56a	65.22	67.22a	64.56a
D_2	65.00	79.44b	66.56	62.33a	60.22ab
D_3	65.44	63.78c	64.67	53.56b	52.22b
LS	**NS**	**	**NS**	**	**
CV (%)	**6.87**	**8.09**	**11.18**	**9.60**	**11.81**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.1.4.3 Interaction effect of different dose and time of nitrogen application

The interaction between the different rates and times of nitrogen did not differ significantly at 30, 60, 75 and 90 DAT, while the most significant (*$p<0.01$*) difference occurred at 45 DAT on leaf number of rice. At 45 DAT, the highest leaf number was 108.00 resulting from D_1 (180 kg urea ha^{-1}) applied in three splits such as 7, 25, 40 DAT (T_1D_1) which was at par (91.33) with 180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT (T_2D_1) while the lowest leaf number were resulting from T_1D_3 (62.33) which was statistically similar to T_2D_3 (64.67), T_3D_1 (75.33), T_3D_2 (76.00) and T_3D_3 (64.33). The number of leaves at 30, 60, 75 and 90 DAT, respectively, remains statistically stable due to the interaction of the different rates and timings of nitrogen treatment

(Table 12). Recommended dose (D_1) provided the highest result where 15 % reduced dose (D_2) provided the lowest result. According to research obtained by Peng *et al.* (2006), nitrogen treatment to rice during its early growth stages can have a good impact on leaf development. In order to maximize leaf and tiller growth in rice agriculture, appropriate nitrogen management techniques should be taken into account both time and dosage (Xu *et al.*, 2012). According to Peng *et al.* (2006), delaying the application of nitrogen is frequently advised since it might improve the vegetative growth phase, which in turn results in better leaf development and eventually increased grain production. Shaiful et al. (2009) observed that the number of leaves hill^{-1} was greatly impacted by the split application of urea.

Table 12. Interaction effect of different dose and time of nitrogen application on leaf number of BRRI dhan87 rice at different DAT

Interaction		Leaf number hill^{-1}				
Time	**Dose**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
T_1	D_1	73.33	108.00a	68.00	67.67	65.33
	D_2	71.33	79.00bc	68.00	66.00	64.33
	D_3	71.67	62.33c	66.67	52.33	51.00
T_2	D_1	62.33	91.33ab	67.67	68.00	65.33
	D_2	64.00	83.33b	68.67	61.00	56.00
	D_3	63.00	64.67c	57.33	50.33	50.33
T_3	D_1	67.33	75.33bc	60.00	66.00	63.00
	D_2	59.67	76.00bc	63.00	60.00	60.33
	D_3	61.67	64.33c	70.00	58.00	55.33
LS		**NS**	**	**NS**	**NS**	**NS**
CV (%)		**6.87**	**8.09**	**11.18**	**9.60**	**11.81**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1%

level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.2 Yield contributing characters

4.2.1 Effective tiller $hill^{-1}$

4.2.1.1 Effect of different time of nitrogen application

The treatment T_1 (Three split nitrogen applications at 7, 25, 40 DAT), T_2 (Three split nitrogen applications at 7, 35, 50 DAT) and T_3 (Three split nitrogen applications at 7, 40, 60 DAT) had no significant difference on effective tiller $hill^{-1}$ of rice. Numerically, the highest (10.22) effective tiller $hill^{-1}$ was found in T_3 (Three split nitrogen applications at 7, 40, 60 DAT) and lowest (9.56) was found in T_1 (Three split nitrogen applications at 7, 25, 40 DAT) (Table 13).

4.2.1.2 Effect of different dose of nitrogen application

The analysis of data revealed that different dose of nitrogen (D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}) had non-significant effect on number of effective tiller $hill^{-1}$. This implies that all treatments provide similar results. Furthermore, there were no major differences in the experimental means among the three treatments. The highest effective tiller $hill^{-1}$ (10.33) was observed from D_1 (180 kg urea ha^{-1}) and lowest value (9.33) was observed from D_3 (153 kg urea ha^{-1}) (Table 14).

4.2.1.3 Interaction effect of different dose and time of nitrogen application

It was observed that the interaction between the rate of nitrogen application and the timing of nitrogen application was non-significant in case of effective tiller $hill^{-1}$. The T_3D_1 treatment (180 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) and T_3D_2 treatment (162 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) were found to be the most effective (10.67) in terms of effective tiller $hill^{-1}$,while the T_1D_2 treatment (162 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) combination yielded the lowest (9.00) effective tiller $hill^{-1}$ (Table 15). A 10% reduced dose (D_2= 162 kg urea ha^{-1}) provided the similar effective tiller as the recommended dose (D_1= 180 kg urea ha^{-1}) with T_3 (Three split nitrogen applications at 7, 40, 60

DAT treatment). Due to the high level of nitrogen in the initial soil sample, as determined by the soil analysis, a 10% reduction in nitrogen dose D_2 (162 kg urea ha^{-1}) provided the similar effective tiller as the recommended dose D_1= 180 kg urea ha^{-1}). Sultana and Ali (2014) have reported that the maximum effective tillers $hill^{-1}$ was obtained from Kachra variety with 60 kg N ha^{-1} and the minimum effective tillers $hill^{-1}$ was obtained from Raniselute variety with 120 N ha^{-1} treatment combinations. Hossan et al. (2008) observed that effective tillers $hill^{-1}$ did not vary significantly by the interaction effect of rice variety and nitrogen level.

4.2.2 Panicle length

4.2.2.1 Effect of different time of nitrogen application

Various nitrogen application time T_1 (Three split nitrogen applications at 7, 25, 40 DAT), T_2 (Three split nitrogen applications at 7, 35, 50 DAT) and T_3 (Three split nitrogen applications at 7, 40, 60 DAT) was highly significant ($p<0.01$) in case of length of the rice panicle. The highest value (22.84 cm) was resulted from T_3 (Three split nitrogen applications at 7, 40, 60 DAT) which was statistically similar to T_1 (Three split nitrogen applications at 7, 25, 40 DAT) and lowest (21.20 cm) was resulted from T_2 (Three split nitrogen applications at 7, 35, 50 DAT) (Table 13).

4.2.2.2 Effect of different dose of nitrogen application

The impact of different doses of nitrogen on panicle length (cm) of rice was not statistically significant. The results of the three treatment regimens identified in the study were not statistically significant. In the experimental environment, the reduced rate of nitrogen (D_2 = 162 kg urea ha^{-1} and D_3 = 153 kg urea ha^{-1}) had the same impact on rice panicle length as the recommended level of nitrogen (D_1 = 180 kg urea ha^{-1}) (Table 14).

4.2.2.3 Interaction effect of different dose and time of nitrogen application

A significant ($p<0.05$) difference was observed due to an interaction effect of the varying rate and time of nitrogen application on panicle length (Table 15). The highest panicle length (24.26 cm) was observed by T_3D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) and the lowest (20.37 cm) was observed by T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) (Table 15). The findings of Yoseftabar (2013) demonstrated that nitrogen fertilizer greatly enhanced panicle number, panicle length, panicle dry matter, total grain and grain yield at a high rate of 300 kg ha^{-1} of N fertilizer. Raza *et al.* (2003), suggested that the panicle length was significantly increased when N was applied in two splits: ½ (half) during the tillering process and ½ (half) at the initiation of the panicle. According to Mondal and Swamy, (2003) the longest panicle length was achieved by applying N @120 kg ha^{-1} as urea in equal splits throughout transplanting, tillering, panicle initiation and flowering.

4.2.3 Filled grain $panicle^{-1}$

4.2.3.1 Effect of different time of nitrogen application

The various time of nitrogen application had a statistically significant ($p<0.01$) effect on filled grain $panicle^{-1}$ of rice. T_1 (Three split nitrogen applications at 7, 25 and 40 DAT) achieved the highest value of 72.54 which was statistically similar to T_2 (Three split nitrogen applications at 7, 35, 50 DAT) with 72.07 whereas the lowest value of 62.01 was achieved at T_3 (Three split nitrogen applications at 7, 40, 60 DAT) (Table 13).

4.2.3.2 Effect of different dose of nitrogen application

Various nitrogen application doses (D_1 =180kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}) had highly significant ($p<0.01$) impact on filled grain $panicle^{-1}$ of rice. The highest value (74.80) was resulted from D_2 treatment (162 kg urea ha^{-1}) which was statistically similar to D_1 treatment (180kg urea ha^{-1}) which was 71.21 and the lowest (60.62) was resulted from D_3 (153 kg urea ha^{-1}) treatment (Table 14).

4.2.3.3 Interaction effect of different dose and time of nitrogen application

A non-significant difference was observed due to an interaction effect of the varying rate and time of nitrogen application on filled grain $panicle^{-1}$ (Table 15). The T_2D_2 treatment (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) provided numerically the highest number of filled grain $panicle^{-1}$ (82.04) and T_3D_3 treatment (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) provided the lowest number of filled grain $panicle^{-1}$ (58.62) (Table 15). Lawal and Lawal, (2002) found that rice grain growth and an increase in the number of filled grains per panicle depend on an appropriate supply of nitrogen. Metwally et al. (2011) examined that number of filled grains $panicle^{-1}$ increased with increase in nitrogen level. Hasanuzzaman et al.

(2012), urea supergranules @ 75 kg ha^{-1} reported the highest value of full grains, which was statistically comparable to applications of 80, 120, and 160 kg N ha^{-1}.

4.2.4 Unfilled grain $panicle^{-1}$

4.2.4.1 Effect of different time of nitrogen application

Different time of nitrogen application had not a significant effect on unfilled grain $panicle^{-1}$ of rice. T_3 (Three split nitrogen applications at 7, 40, 60 DAT) achieved the highest value of 17.98 whereas the lowest value of 17.35 was achieved at T_2 (Three split nitrogen applications at 7, 35, 50 DAT) (Table 13).

4.2.4.2 Effect of different dose of nitrogen application

The treatment (D_1 =180kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}) had highly significant (*$p<0.01$*) effect on unfilled grain $panicle^{-1}$ of rice. The highest value (21.29) was resulted from D_3 treatment (153 kg urea ha^{-1}) and the lowest (13.12) was resulted from D_1 (180 kg urea ha^{-1}) treatment (Table 14).

4.2.4.3 Interaction effect of different dose and time of nitrogen application

There was a non-significant difference due to an interaction effect of the varying rate and time of nitrogen application on unfilled grain $panicle^{-1}$. T_3D_3 treatment (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) provided the highest number of unfilled grain $panicle^{-1}$ (21.65) and T_2D_1 treatment (180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) provided the lowest number of unfilled grain $panicle^{-1}$ (12.50) (Table 15). According to Tabrizi et al. (2011), limiting the source and the relationship between the sink and the source for producing more photo assimilates resulted in a reduction in the amount of filled grain that was observed. This increased the number of unfilled spikelets, which in turn decreased spikelet fertility.

Table 13. Effect of different time of nitrogen application on yield contributing characters of BRRI dhan87 rice

Time	Effective tiller hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}
T_1	9.56	22.24a	72.55a	17.59
T_2	9.78	21.20b	72.07a	17.35
T_3	10.22	22.84a	62.01b	17.98
LS	**NS**	**	*	**NS**
CV (%)	**10.15**	**3.62**	**11.66**	**5.68**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split applications at 7, 35, 50 DAT and T_3 =Three split applications at 7, 40, 60 DAT.

Table 14. Effect of different dose of nitrogen application on yield contributing characters of BRRI dhan87 rice

Dose	Effective tiller hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}
D_1	10.33	21.79	71.21a	13.12c
D_2	9.89	22.39	74.80a	18.50b
D_3	9.33	22.11	60.62b	21.29a
LS	**NS**	**NS**	**	**
CV (%)	**10.15**	**3.62**	**11.66**	**5.68**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

Table 15. Interaction effect of different dose and time of nitrogen application on yield contributing characters of BRRI dhan87 rice

Interaction		Effective tiller hill^{-1}	Panicle length (cm)	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}
Time	Dose				
T_1	D_1	10.33	22.12a-c	72.52	13.08
	D_2	9.00	22.54a-c	81.88	18.65
	D_3	9.33	22.05a-c	63.24	21.04
T_2	D_1	10.00	21.63bc	74.19	12.50
	D_2	10.00	20.37c	82.04	18.33
	D_3	9.33	21.61bc	59.98	21.20
T_3	D_1	10.67	21.62bc	66.91	13.77
	D_2	10.67	24.26a	60.49	18.53
	D_3	9.33	22.66ab	58.62	21.65
LS		**NS**	*	**NS**	**NS**
CV (%)		**10.15**	**3.62**	**11.66**	**5.68**

Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar. LS = Level of significance, NS = Not significant, * = Significant at 5% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.2.5 1000 grain weight

4.2.5.1 Effect of different time of nitrogen application

The analysis of variance revealed a highly significant (*$p<0.01$*) difference on 1000 grain weight of tested rice due to the three nitrogen application time (Figure 1). There were significant pairwise differences among the means. T_1 (Three split nitrogen applications at 7, 25, 40 DAT) treatment yielded the highest 1000 grain weight of 22.85 g, while T_3 (Three split nitrogen applications at 7, 35, 50 DAT) treatment yielded the lowest 1000 grain weight of 21.49 g (Figure 1).

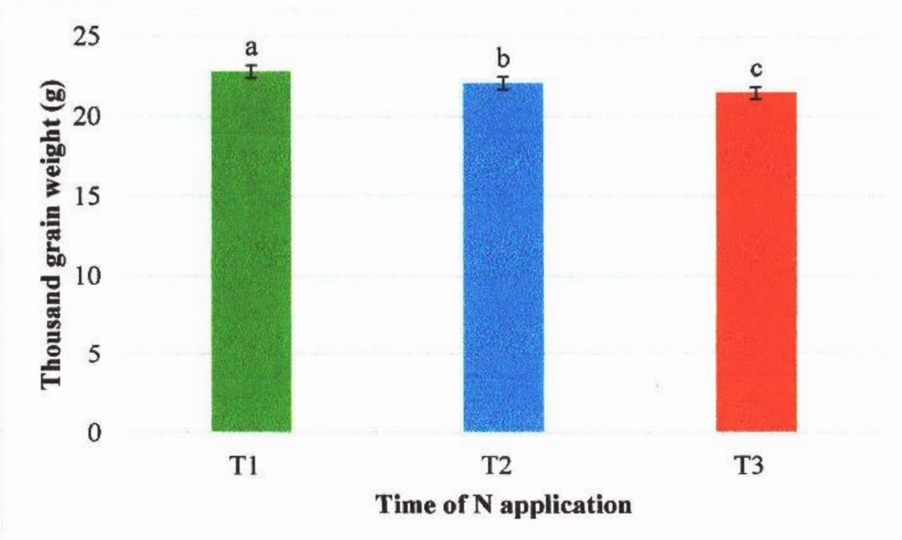

Figure 1. Effect of different time of nitrogen application on 1000 grain weight of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.2.5.2 Effect of different dose of nitrogen application

It was demonstrated that the impact of varying rates of nitrogen application was highly significant (*$p<0.01$*) on 1000 grain weight of rice. The results of the analysis indicated that, on the basis of the average results of all three treatments, the D_1 (180 kg urea ha^{-1}) treatment satisfactorily met the 1000 grain weight. The 1000 grain weight in D_2 (162 kg urea ha^{-1}) was higher than that of D_3 (153 kg urea ha^{-1}) but the highest 1000 grain weight was observed in D_1 (180 kg urea ha^{-1}) which was 23.95g. D_2 (162 kg urea ha^{-1}) produced intermediate levels of 1000 grain weight (22.39 g), while D_3 (152 kg urea ha^{-1}) produced the lowest 1000 grain weight (20.11 g) (Figure 2).

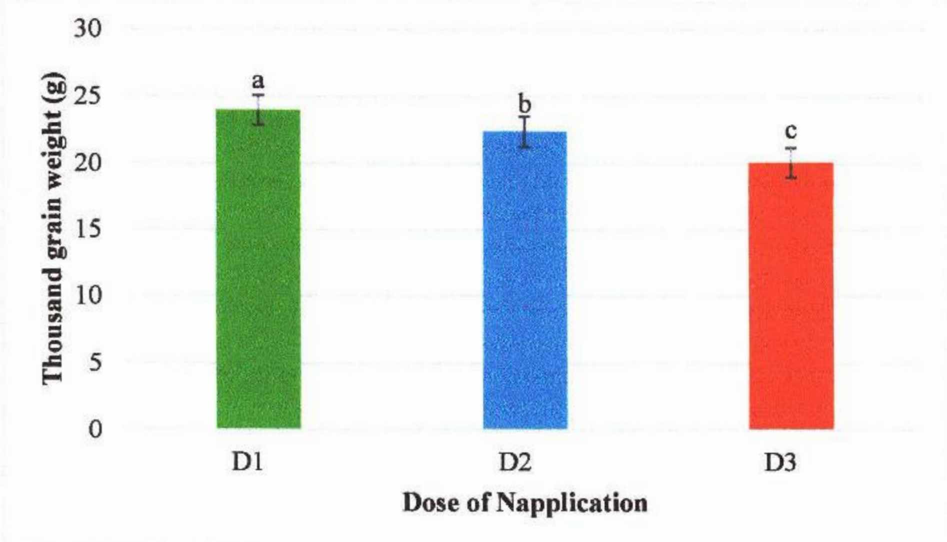

Figure 2. Effect of different dose of nitrogen application on 1000 grain weight of BRRI dhan87 rice. D_1 = 180 kg urea ha^{-1}, D_2= 162 kg urea ha^{-1} and D_3 = 153 kg urea ha^{-1}

4.2.5.3 Interaction effect of different dose and time of nitrogen application

The results pertaining to combined effect of different dose and time of nitrogen application of rice on 1000 grain weight of rice differed significantly (*$p<0.05$*), as illustrated in Figure 3. T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) was the most effective N management for 1000 grain weight, yielded 24.76 g. T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) was the least effective and the lowest value, yielded 19.72 g which was statistically comparable to T_2D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) yielded 20.17 g and T_1D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) yielded 20.45 g (Figure 3). Islam et al. (2008) observed that the highest 1000 grain weight (12.0 g) was obtained by 150 kg N ha^{-1} and the lowest 1000 grain weight (10.7 g) was obtained by control treatment (0 kg N ha^{-1}). According to the finding of Rony et al. (2019), the highest 1000 grain weight (16.66 g) was obtained by 90 kg N ha^{-1} and 60 kg N ha^{-1}.

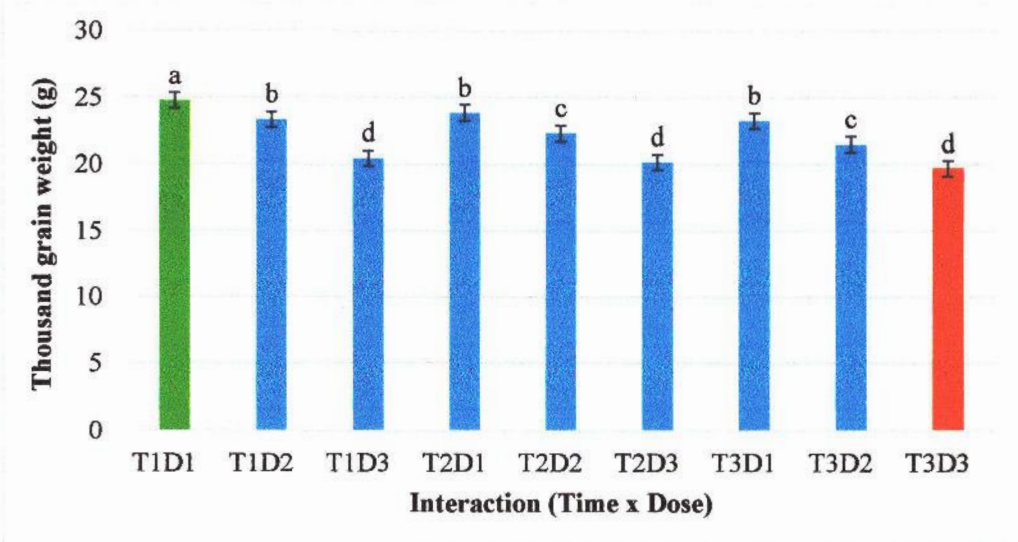

Figure 3. Interaction effect of different dose and time of nitrogen (N) application on 1000 grain weight of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.3 Yield parameters

4.3.1 Grain yield (g $hill^{-1}$)

4.3.1.1 Effect of different time of nitrogen application

The timing of nitrogen application was statistically highly significant ($p<0.01$) in terms of grain yield of rice. The highest (15.82 g $hill^{-1}$) grain yield was achieved from T_1 (Three split nitrogen applications such as 7, 25, 40 DAT) which was statistically similar to T_2 (Three split nitrogen applications such as 7, 35, 50 DAT) with 15.67 g $hill^{-1}$ while the lowest (13.68 g $hill^{-1}$) grain yield was achieved from T_3 (Three split nitrogen applications at 7, 40, 60 DAT) treatment (Figure 4).

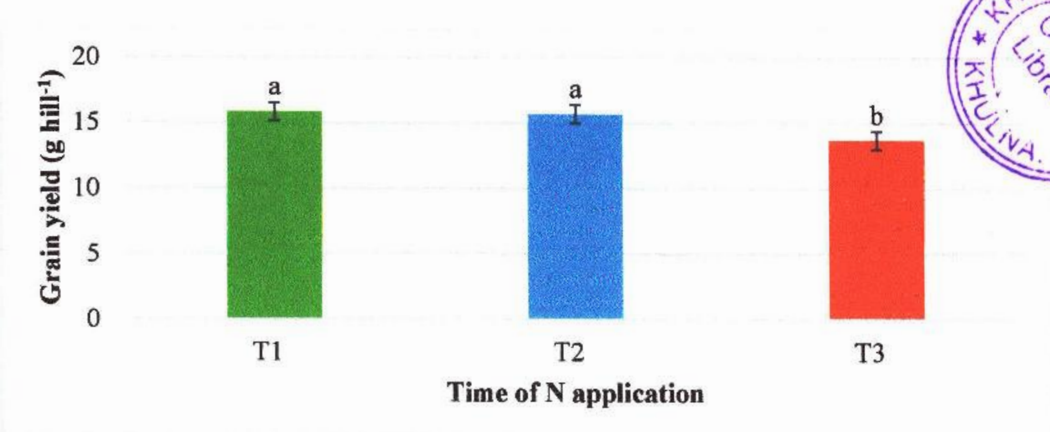

Figure 4. Effect of different time of nitrogen application on grain yield of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3=Three split nitrogen applications at 7, 40, 60 DAT.

4.3.1.2 Effect of different dose of nitrogen application

Statistical analysis of variance revealed that the effect of varying rates of nitrogen application on grain yield was shown to be highly significant (*$p<0.01$*). By comparing the means in pairs, there was considerable variability among the three treatments. D_1 (180 kg urea ha^{-1}) treatment yielded the highest grain yield with 17.46 g $hill^{-1}$ which was statistically similar to D_2 (162 kg urea ha^{-1}) with 16.34 g $hill^{-1}$ and D_3 (153 kg urea ha^{-1}) treatment yielded the lowest grain yield with 11.36 g $hill^{-1}$ (Figure 5). Research finding showed that by 10% reduction in N dose no significant yield loss was noticed which might be due to the soil contained high level of N.

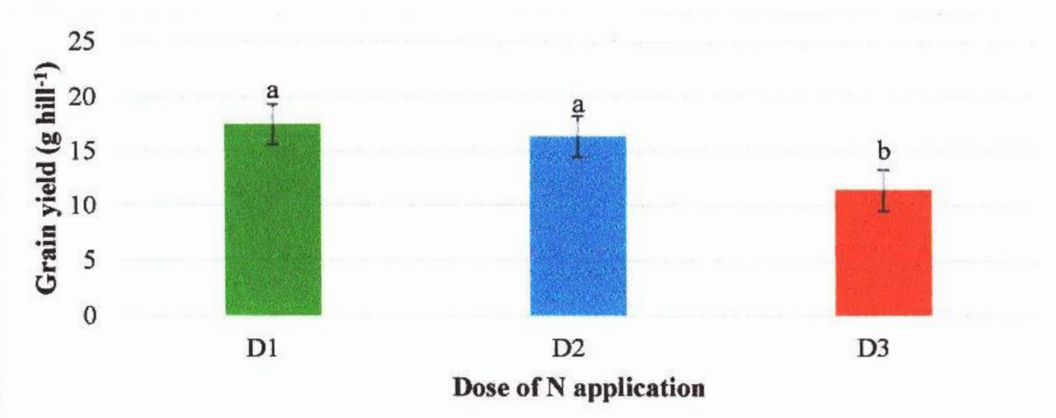

Figure 5. Effect of different dose of nitrogen application on grain yield of BRRI dhan87 rice. D_1 = 180 kg urea ha^{-1}, D_2= 162 kg urea ha^{-1} and D_3 = 153 kg urea ha^{-1}.

4.3.1.3 Interaction effect of different dose and time of nitrogen application

The interaction between the different rates and times of nitrogen application had a significant effect on grain yield of rice. Grain yield increased or decreased as a result of interaction of different treatments (Nitrogen application time and nitrogen dose). According to the findings, T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) had the highest (18.38 g hill^{-1}) grain yield value which was statistically similar to T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) with 18.18 g hill^{-1}, T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) with 17.53 g hill^{-1}, T_1D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) with 17.07 g hill^{-1}, while T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) had the lowest grain yield value (10.75 g hill^{-1}) (Figure 6). 10% reduced dose of nitrogen (D_2= 162 kg urea ha^{-1}) provided the similar result as the recommended dose (D_1= 180 kg urea ha^{-1}) with recommended time (T_1=Three split nitrogen applications at 7, 25, 40 DAT) and 10 days delayed time (T_2=Three split nitrogen applications at 7, 35, 50 DAT). From the soil analysis, it was found that the initial soil of the experiment had high level of nitrogen that's why 10% reduced dose of nitrogen (D_2= 162 kg urea ha^{-1}) provided the similar grain yield as the recommended dose (D_1= 180 kg urea ha^{-1}) with T_1 (Three split nitrogen applications at 7, 25, 40 DAT) treatment and the treatment with 10 days delayed application of 2nd and 3rd slit i.e. T_2 (Three split nitrogen applications at 7, 35, 50 DAT). The amount of grain produced and the yield of straw differ in how fertilizer is managed stated by Rahman et al. (2016). According to Singh et al. (2005), each increased dosage of nitrogen considerably enhanced grain production. Ahmed et al, (2005) observed that the maximum grain yield (4.02 t ha^{-1}) was produced when N was applied @ 40 kg ha^{-1}. Jisan et al. (2014) observed that, BRRI dhan52 fertilized with 75 kg N ha^{-1} appeared at the most promising combination for transplant *aman* rice cultivation in terms of grain yield among the four levels of N, namely 0, 46, 60, and 75 kg ha^{-1}.

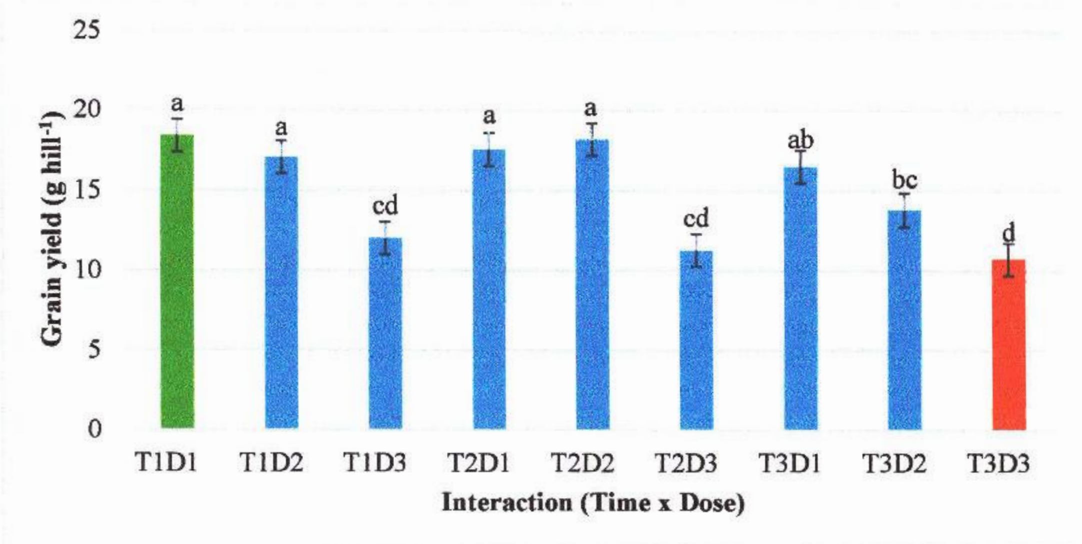

Figure 6. Interaction effect of different dose and time of nitrogen (N) application on grain yield of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.3.2 Biological yield

4.3.2.1 Effect of different time of nitrogen application

On biological yield of rice, the treatment had a highly significant ($p<0.01$) effect. The highest biological yield (48.12 g $hill^{-1}$) was obtained from T_1 (Three split nitrogen applications such as 7, 25, 40 DAT) which was statistically similar to T_2 (Three split nitrogen applications such as 7, 35, 50 DAT) with 47.30 g $hill^{-1}$ and the lowest one (45.45 g $hill^{-1}$) was obtained from T_3 (Three split nitrogen applications such as 7, 40, 60 DAT) (Figure 7).

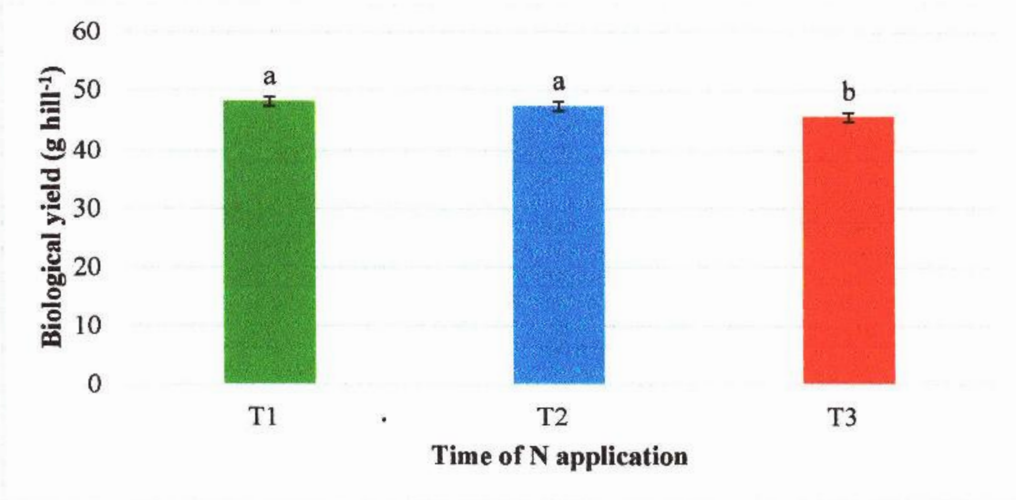

Figure 7. Effect of different time of nitrogen application on biological yield of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.3.2.2 Effect of different dose of nitrogen application

The effect of nitrogen rate showed highly significant ($p<0.01$) variation on biological yield of rice. Maximum biological yield (51.59 g hill^{-1}) was resulted at D_1 (180 kg urea ha^{-1}) which was statistically similar to D_2 (162 kg urea ha^{-1}) with 51.27 g hill^{-1}. The minimum biological yield (38.008 g hill^{-1}) was obtained from D_3 (153 kg urea ha^{-1}) (Figure 8).

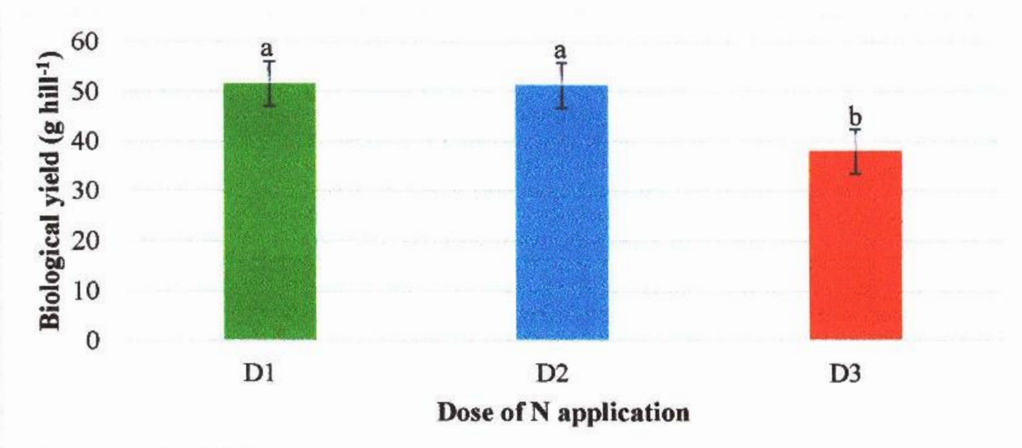

Figure 8. Effect of different dose of nitrogen application on biological yield of BRRI dhan87 rice. D_1 = 180 kg urea ha^{-1}, D_2= 162 kg urea ha^{-1} and D_3 = 153 kg urea ha^{-1}.

4.3.2.3 Interaction effect of different dose and time of nitrogen application

The study revealed that the interaction effect of different time and rate of nitrogen application had significant ($p<0.05$) effect on biological yield. The highest biological yield (52.36 g hill^{-1}) was found at T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) which had no significant different with T_1D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT), T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT), T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) and T_3D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT). On the other hand, the minimum biological yield (35.58 g hill^{-1}) was obtained from the treatment T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) (Figure 9). The highest biological yield was observed from the treatment 120 kg N ha^{-1} with BRRI dhan38 rice variety according to Hossain et al. (2008). In the experiment of Ahmed et al. (2005), the highest biological yield was produced by 40 kg N ha^{-1} which was statistically identical with other fertilizers (20 kg ha^{-1}, 60 kg ha^{-1}, 80 kg ha^{-1}) except with 0 kg N ha^{-1}.

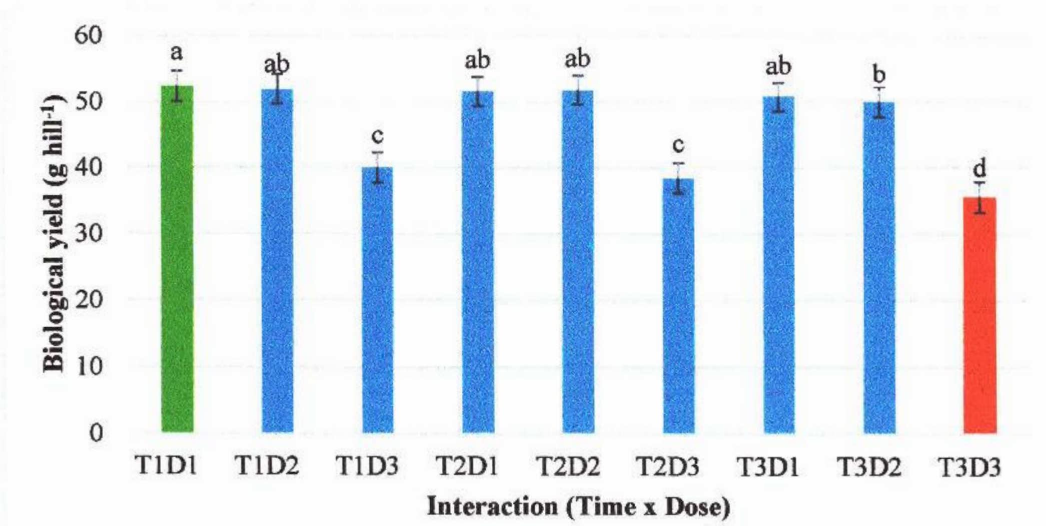

Figure 9. Interaction effect of different dose and time of nitrogen application on biological yield of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.3.3 Harvest index

4.3.3.1 Effect of different time of nitrogen application

The timing of nitrogen (N) application had a significant (*$p<0.05$*) impact on harvest index (Figure 10). The highest harvest index (32.79 %) was achieved from T_2 (Three split application at 7, 35, 50 DAT) which was statistically at par with T_1 (Three split nitrogen applications at 7, 25, 40 DAT) while the lowest harvest index (30.08 %) was achieved from T_3 (Three split applications at 7, 40, 60 DAT) treatment (Figure 10).

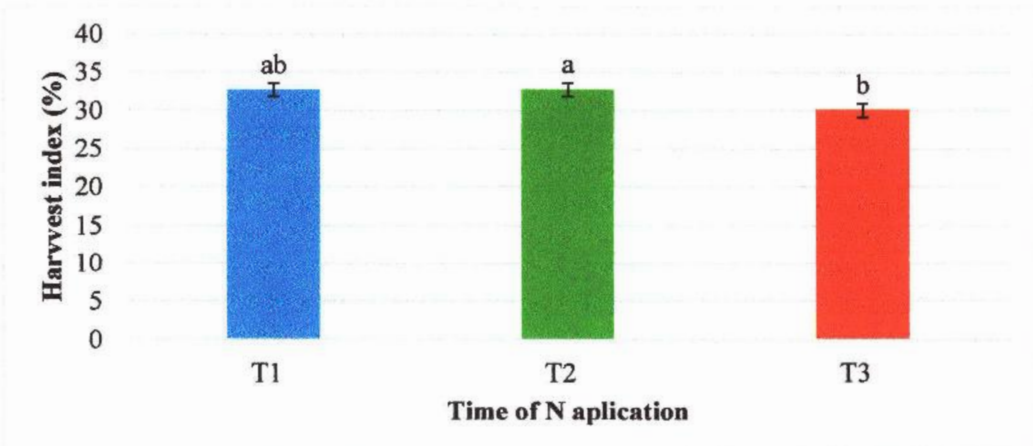

Figure 10. Effect of different time of nitrogen application on harvest index of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.3.3.2 Effect of different dose of nitrogen application

Statistical analysis of variance revealed that varying rates of nitrogen application was shown to be highly significant (*$p<0.01$*) on harvest index of rice. By comparing the means in pairs, there was considerable variability among the three treatments. D_1 (180 kg urea ha^{-1}) treatment yielded the highest (33.83 %) and D_3 (153 kg urea ha^{-1}) treatment yielded the lowest harvest index (29.89 %). D_2 (162 kg urea ha^{-1}) treatment provided the indifferent result (31.82 %) with D_1 (180 kg urea ha^{-1}) (Figure 11).

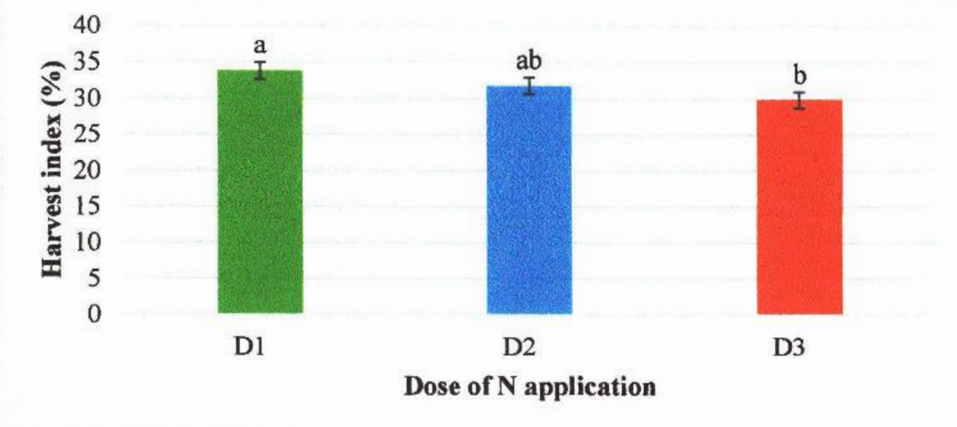

Figure 11. Effect of different dose of nitrogen application on harvest index of BRRI dhan87. D_1 = 180 kg urea ha^{-1}, D_2= 162 kg urea ha^{-1} and D_3 = 153 kg urea ha^{-1}.

4.3.3.3 Interaction effect of different dose and time of nitrogen application

The interaction effects of nitrogen rate and nitrogen timing on the harvest index were found to be significant (*p<0.05*). Harvest index of rice remained similar among most of the treatment combinations (Nitrogen application time and nitrogen dose). According to the findings, T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) had the highest HI value of 35.13 % which was identical to T_2D_2 (162 kg urea ha^{-1} applied at three splits such as 7, 35, 50 DAT) with 35.07 % and T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) with 33.93 %. T_3D_2 (162 kg urea ha^{-1} applied at three splits such as 7, 40, 60 DAT) had the lowest HI value of 27.63 % (Figure 12). With 10% reduced dose of nitrogen (D_2= 162 kg urea ha^{-1}) with 10 days delayed application time (Three splits nitrogen application at 7, 35, 50 DAT) provided the similar result as the recommended dose (D_1= 180 kg urea ha^{-1}) with recommended time (Three splits nitrogen applications at 7, 25, 40 DAT) and 10 days delayed time (Three splits nitrogen applications at 7, 35, 50 DAT). According to the soil analysis, the initial soil had a high level of nitrogen, which is why a 10% reduction in nitrogen dose (D_2= 162 kg urea ha^{-1}) produced a significantly similar result as the recommended dose (D_1= 180 kg urea ha^{-1}). When nitrogen was administered to Basmati rice at a rate of 100 kg ha^{-1}, Ehsanullah et al. (2012) obtained the highest harvest index. Pramanik and Bera, (2013) found a substantial impact of nitrogen on harvest index, with greatest harvest index seen when nitrogen was applied @ 150 kg ha^{-1} and minimum harvest index in the case of control with no nitrogen treatment.

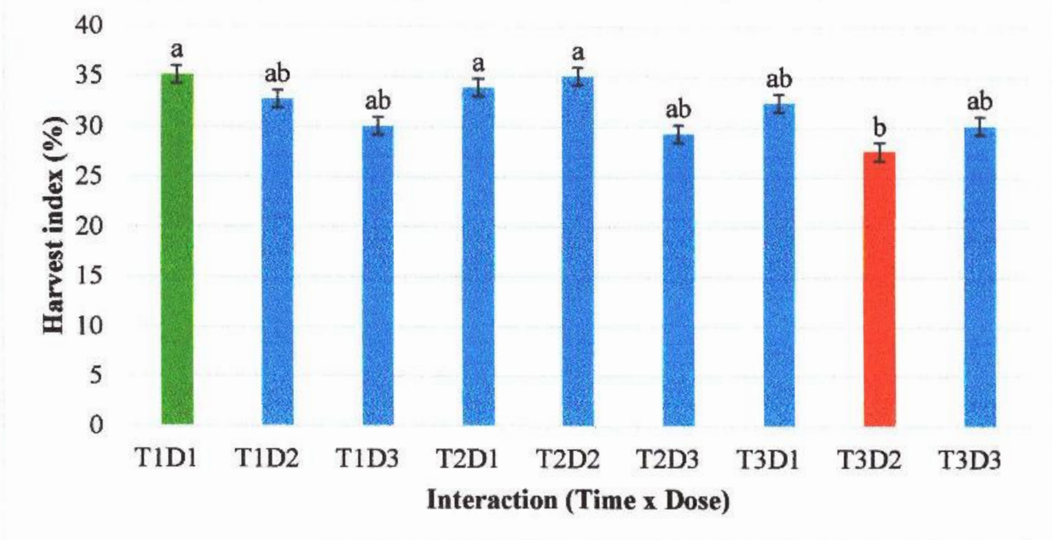

Figure 12. Interaction effect of different dose and time of nitrogen (N) application on harvest index of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.4 Nitrogen use efficiency

4.4.1 Effect of different time of nitrogen application

The frequency of nitrogen application in rice plant was statistically highly significant ($p<0.01$) in terms of nitrogen use efficiency. The highest (57.51 g/g) nitrogen use efficiency was achieved from T_1 (Three split application such as 7, 25, 40 DAT) which was statistically similar to T_2 (Three split application such as 7, 35, 50 DAT) with 56.99 g/g while the lowest (49.69 g/g) nitrogen use efficiency was achieved from T_3 (Three split applications at 7, 25, 40 DAT) treatment (Figure 13).

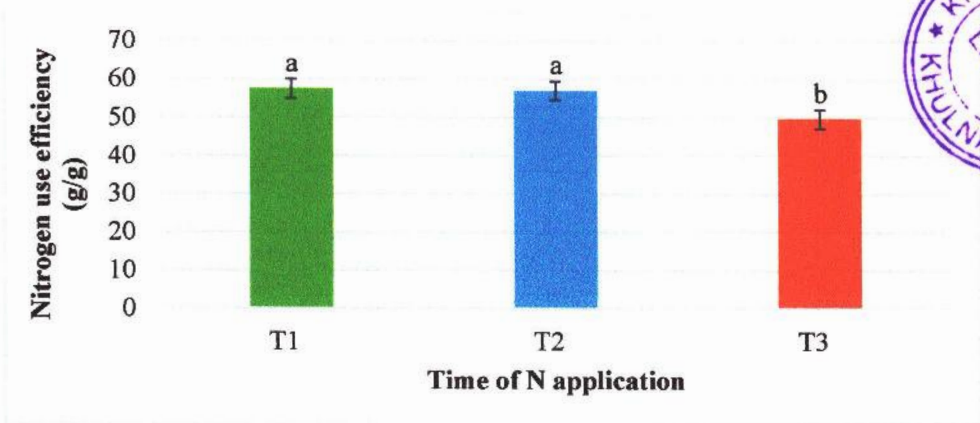

Figure 13. Effect of different time of nitrogen application on nitrogen use efficiency of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT.

4.4.2 Effect of different dose of nitrogen application

Different rates of nitrogen application on nitrogen use efficiency of rice was shown to be highly significant ($p<0.01$) evaluated in the analysis of variance (Figure 14). The highest (60.53 g/g) nitrogen use efficiency was found in D_2 (162 kg urea ha^{-1}) which was statistically similar to D_1 (180 kg urea ha^{-1}) with 58.21 g/g while the lowest (45.45 g/g) nitrogen use efficiency was achieved from D_3 (153 kg urea ha^{-1}) treatment. Therefore, the best utilization of nitrogen applied in the field was respectively 162 kg urea ha^{-1} and 180 kg urea ha^{-1} which was represented by D_2 and D_1 treatment (Figure 14).

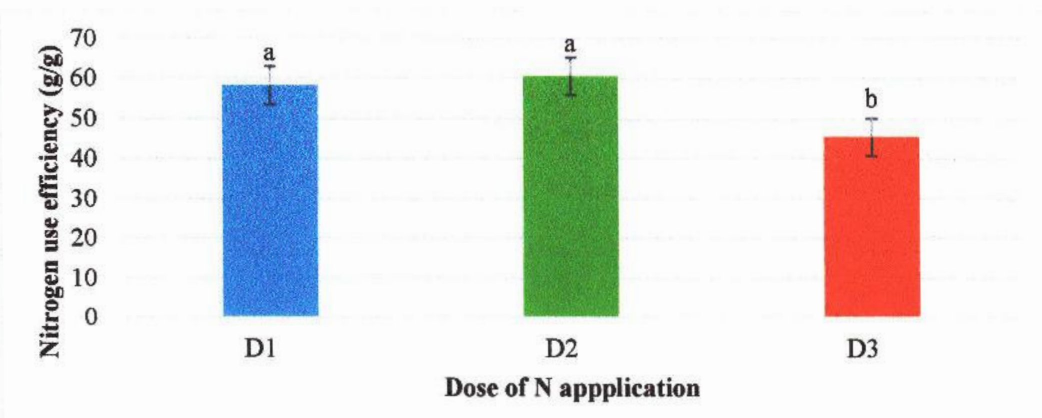

Figure 14. Effect of different dose of nitrogen application on nitrogen use efficiency of BRRI dhan87 rice. D_1 = 180 kg urea ha^{-1}, D_2= 162 kg urea ha^{-1} and D_3 = 153 kg urea ha^{-1}.

4.4.3 Interaction effect of different dose and time of nitrogen application

The combined effects of nitrogen amount and nitrogen timing on the nitrogen use efficiency of rice was found to be significant (*$p<0.05$*) (Figure 15). Nitrogen use efficiency increased or decreased as a result of interaction of different treatments, according to the results. According to the findings, T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) had the highest (67.33 g/g) NUE value which was statistically similar to T_1D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) with 63.11 g/g, T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) with 61.27 g/g, T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) with 58.42 g/g, while T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) had the lowest NUE value (42.98 g/g) (Figure 15). In a study conducted by Baba et al. (2010), the highest nitrogen use efficiency (NUE) was observed when a rice crop was treated with 120 kg ha^{-1} nitrogen. Application of nitrogen at 210 kg ha^{-1} led to the greatest nitrogen utilization rate and highest grain yield (Liang et al., 2021). As nitrogen levels increased further, the NUE dropped. This is due to the fact that absorption outpaces use at greater nitrogen concentrations. According to Haque and Haque (2016), BU dhan1 had the most nitrogen use efficiency when treated with 60 kg N ha^{-1} among the six nitrogen levels 0, 20, 40, 60, 80 and 100 kg N ha^{-1}. Yaduvanshi (2003) asserted that NUE decreased with an increase in the rates of N fertilizer from 60 to 120 and 180 kg N ha^{-1}.

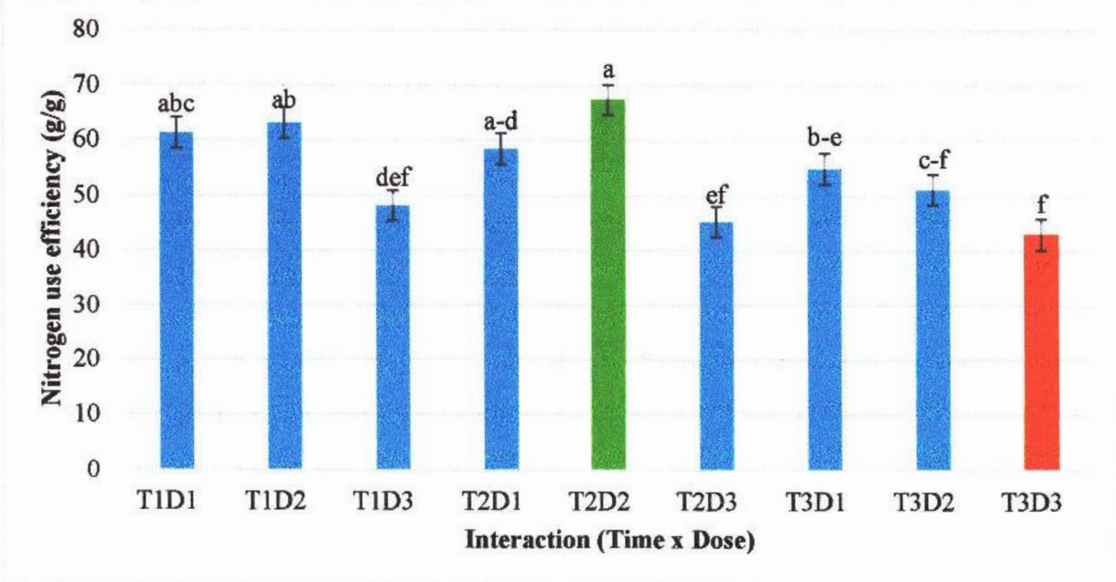

Figure 15. Interaction effect of different dose and time of nitrogen (N) application on nitrogen use efficiency of BRRI dhan87 rice. T_1 =Three split nitrogen applications at 7, 25, 40 DAT, T_2 =Three split nitrogen applications at 7, 35, 50 DAT and T_3 =Three split nitrogen applications at 7, 40, 60 DAT. D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}.

4.5 Functional relationship between filled grain panicle^{-1} and grain yield

According to a simple linear regression, there was a significant ($p<0.05$) positive correlation between grain yield and the quantity of filled grain panicle^{-1} of rice. The line of regression of Y (Grain yield) on X (Filled grain panicle^{-1}) having equation y = 0.2032x + 1.0624. From the figure, it was found that there was functional connection between filled grain panicle^{-1} and grain yield of rice. This implies that rice grain yield was influenced by filled grain panicle^{-1}, with change in filled grain panicle^{-1} accounting for 52% of the variation in grain yield (Figure 16).

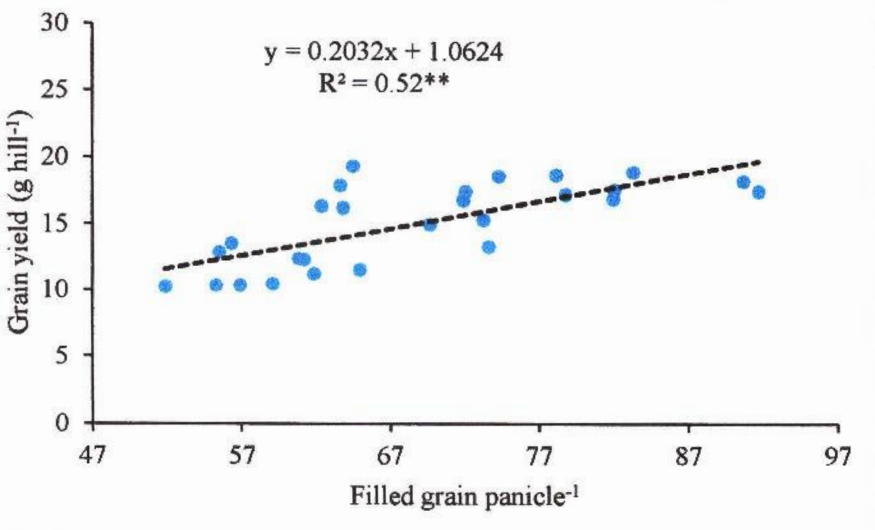

Figure 16. Functional relationship between filled grain panicle^{-1} and grain yield (g hill^{-1})

4.6 Functional relationship between 1000 grain weight and grain yield

There was a linear and significantly (*$p<0.05$*) positive relationship between 1000 grain weight (g) and grain yield (g hill^{-1}) of BRRI dhan87 aman rice. The functional equation $y = 1.601x - 20.407$ and correlation coefficient $R^2 = 0.804$ suggested that 80% of the variation in grain production could be explained by the variation in 1000 grain weight. The rate of grain yield often increases along with an increase in the weight of 1000 grains. As anticipated, the maximum grain yield (18.38 g hill^{-1}) was found from D_1 (180 kg ha^{-1}) with T_1 (Three split application such as 7, 25, 40 DAT) treatment where 1000 grain weight (24.76 g) was also maximum (Figure 17). According to the experiment of Rony et al. (2019), grain yield and thousand grain weight (g) had a simple linear relationship which means grain yield increased with an increase in thousand grain weight (g) and above (14%) of the variation in grain yield could be explained.

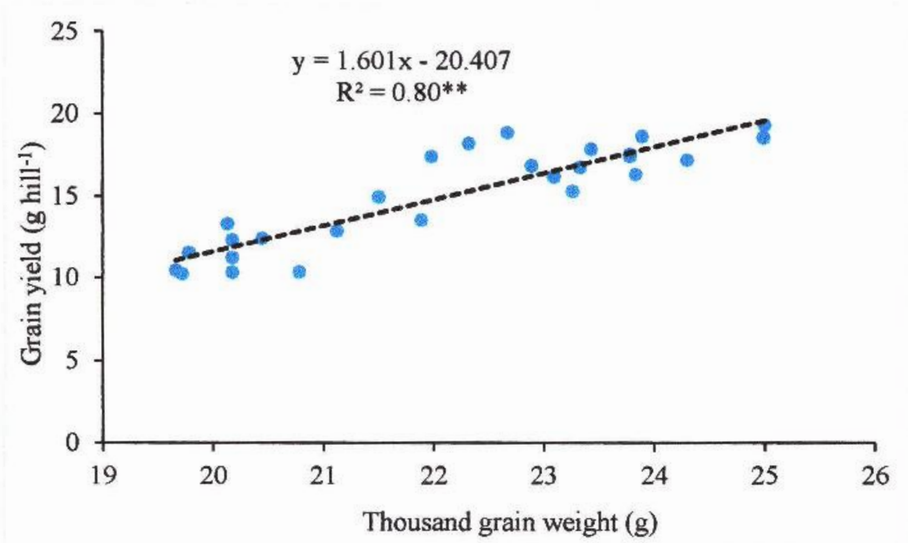

Figure 17. Functional relationship between thousand grain weight (g) and grain yield (g $hill^{-1}$)

CHAPTER V

SUMMARY AND CONCLUSION

The pot experiment was carried out throughout Aman season from July 17, 2022 to November 17, 2022 with HYV BRRI dhan87, with the aim of studying the effect of different times and rates of nitrogen application on growth, yield and yield contributing parameters in rice. The experiment was conducted in Professor Purnendu Gain Field Laboratory of the Agrotechnology Discipline of Khulna University in Khulna under Agro-ecological zone 13, which is part of the Gangetic tidal floodplain. The experiment was conducted in Complete Randomized Design (CRD) with three replications.

The experimental treatment consisted of two factors such as: 1. Nitrogen (urea) dose, 2. Nitrogen (urea) application time. Three different dose of nitrogen application were: D_1= 180 kg urea ha^{-1} (Recommended dose), D_2= 162 kg urea ha^{-1} (10% less), D_3= 153 kg urea ha^{-1} (15% less) and three different time of nitrogen application were: T_1= Three split application at 7, 25, 40 days after transplanting (DAT) (Recommended), T_2= Three split application at 7, 35, 50 DAT, T_3= Three split application at 7, 40, 60 DAT. The data on growth parameters such as plant height, tiller number hill^{-1}, leaf number hill^{-1}, SPAD value and yield contributing parameters such as effective tiller hill^{-1}, panicle length, 1000 grain weight, grain yield, biological yield, harvest index and nitrogen use efficiency were also collected from the experimental rice plant.

Nitrogen dose (D_1= 180 kg ha^{-1}, D_2= 162 kg ha^{-1}, D_3= 153 kg ha^{-1}) mostly showed significant impact on growth characters like plant height, tiller number, leaf number and SPAD (Soil Plant Analysis Development) value rather than nitrogen application time (T_1= Three split nitrogen applications at 7, 25, 40 DAT, T_2= Three split nitrogen applications at 7, 35, 50 DAT, T_3= Three split nitrogen applications at 7, 40, 60 DAT) . Due to the combined effect of different time and rate of nitrogen application on growth characters mostly exhibited non-significant impact.

Analysis of data showed that there were significant relationship in case of yield parameters (grain yield, biological yield, harvest index). The impact of interaction of different time and dose of nitrogen application were significantly affected by yield contributing characters (effective tiller, panicle length, filled grain panicle^{-1}, unfilled grain panicle^{-1} and 1000 grain weight). Interaction effect of different time and dose of nitrogen application showed non-significant variance on effective tiller and panicle length. Effective tiller performed better at T_3D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) with 10.67 followed by T_3D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) with 10.67 and panicle length performed better at T_3D_2 (162 kg urea ha^{-1} applied at three split application such as 7, 40, 60 DAT) whereas the lowest effective tiller (9.00) and panicle length (20.37cm) showed at T_1D_2 and T_2D_2 respectively. In case of 1000 seed weight, T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) performed better and T_3D_3 (153 kg urea ha^{-1} applied at three splits such as 7, 40, 60 DAT) performed the lowest.

According to the findings, the highest grain yield (18.38 g $hill^{-1}$) was obtained from T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) followed by T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) with 18.18 g $hill^{-1}$, T_2D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) with 17.53 g $hill^{-1}$, T_1D_2 (162 kg urea ha^{-1} applied at three splits such as 7, 25, 40 DAT) with 17.07 g $hill^{-1}$, while T_3D_3 (153 kg urea ha^{-1} applied at three splits such as 7, 40, 60 DAT) had the lowest grain yield value (10.75 g $hill^{-1}$). The highest biological yield (52.36 g $hill^{-1}$) was obtained from T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) and T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) provided the lowest biological yield (35.58g $hill^{-1}$). Combined effect of varying time and dose of nitrogen application showed significant variance on harvest index. T_1D_1 (180 kg urea ha^{-1} applied in three splits such as 7, 25, 40 DAT) had the highest HI value of 35.13 % and T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT) had the lowest HI value of 27.63 %. Different time and dose of nitrogen application was significantly affected in case of nitrogen use efficiency where NUE showed highest result (67.33 g/g) at T_2D_2 (162 kg urea ha^{-1} applied in three splits such as 7, 35, 50 DAT) treatment and lowest result (42.98 g/g) at T_3D_3 (153 kg urea ha^{-1} applied in three splits such as 7, 40, 60 DAT).

The results of this investigation suggest that combined effect of different time and rate of nitrogen application had non-significant effect on yield contributing characteristics, effective tiller and filled grain $panicle^{-1}$ but 1000 grain weight varied significantly which was the highest with 180 kg urea ha^{-1} (D_1) along with T_1 (Three split nitrogen applications at 7, 25, 40 DAT) treatment. The performance of the yield parameters grain yield, biological yield and harvest index were improved when treated with 180 kg urea ha^{-1} (D_1, recommended dose) treatment along with application time T_1 and T_2. With the same application time (T_1 and T_2) and 10% reduction in nitrogen dose D_2 (162 kg urea ha^{-1}), indifferent results were obtained but with 15% reduction of nitrogen dose D_3 (153 kg urea ha^{-1}) produced lower values. In case of nitrogen use efficiency (NUE), D_2 (162 kg urea ha^{-1}) along with T_2 and T_1 was found to be more effective.

In areas where the soil nitrogen content exceeds the average value, a 10% reduced nitrogen dose (162 kg urea ha^{-1}) can be administered, since it yields a grain yield that is comparable to that of the recommended dose (180 kg urea ha^{-1}). It may be concluded that for aman rice variety BRRI dhan87, 10% of the urea dose can be reduced by 10 days delayed in 2nd and 3rd split application i.e. 7, 35, 50 DAT instead of 7, 25, 40 DAT without significant yield loss.

CHAPTER VI

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APPENDICES

Appendix I. Effect of different time of urea (nitrogen) application on yield and yield contributing characters of BRRI dhan87 rice

Time	1000 seed weight (g)	Grain yield (g hill^{-1})	Biological yield (g hill^{-1})	Harvest index (%)
T_1	22.85a	15.82a	48.12a	32.66ab
T_2	22.11b	15.67a	47.30a	32.79a
T_3	21.49c	13.68b	45.45b	30.08b
LS	**	**	**	*
CV%	**1.32**	**6.95**	**1.70**	**6.87**

LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split applications at 7, 25, 40 DAT, T_2 =Three split applications at 7, 35, 50 DAT and T_3 =Three split application at 7, 40, 60 DAT. Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar.

Appendix II. Effect of different dose of urea (nitrogen) application on yield and yield contributing characters of BRRI dhan87 rice

Dose	1000 seed weight (g)	Grain yield (g hill^{-1})	Biological yield (g hill^{-1})	Harvest index (%)
D_1	23.95a	17.46a	51.60a	33.83a
D_2	22.39b	16.34a	51.27a	31.82ab
D_3	20.11c	11.36b	38.00b	29.89b
LS	**	**	**	**
CV%	**1.32**	**6.95**	**1.70**	

LS = Level of significance, * = Significant at 5% level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}. Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar.

Appendix III. Interaction effect of different dose and time of urea (nitrogen) application on yield and yield contributing characters of BRRI dhan87 rice

Interaction Time	Dose	1000 seed weight (g)	Grain yield (g $hill^{-1}$)	Biological yield (g $hill^{-1}$)	Harvest index (%)
T_1	D_1	24.76a	18.38a	52.38a	35.13a
	D_2	23.33b	17.04a	51.99ab	32.77ab
	D_3	20.45d	12.04cd	40.01c	30.09ab
T_2	D_1	23.83b	17.53a	51.63ab	33.93a
	D_2	22.32c	18.18a	51.85ab	35.07a
	D_3	20.17d	11.3cd	38.43c	29.37ab
T_3	D_1	23.26b	16.48ab	50.807ab	32.43ab
	D_2	21.50c	13.81bc	49.96b	27.63b
	D_3	19.72d	10.75d	35.58d	30.19ab
LS		*	*	*	*
CV%		**1.32**	**6.95**	**1.70**	**6.87**

LS = Level of significance, * = Significant at 5% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split applications at 7, 25, 40 DAT, T_2 =Three split applications at 7, 35, 50 DAT and T_3 =Three split application at 7, 40, 60 DAT. D_1 =180kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}. Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar.

Appendix IV. Effect of different time of urea (nitrogen) application on nitrogen use efficiency (NUE) of BRRI dhan87 rice

Time	Nitrogen use efficiency (NUE)
T_1	57.51a
T_2	56.98a
T_3	49.69b
LS	**
CV%	**7.03**

LS = Level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, T_1 =Three split applications at 7, 25, 40 DAT, T_2 =Three split applications at 7, 35, 50 DAT and T_3 =Three split application at 7, 40, 60 DAT. Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar.

Appendix V. Effect of different dose of urea (nitrogen) application on nitrogen use efficiency (NUE) of BRRI dhan87 rice

Dose	Nitrogen use efficiency (NUE)
D_1	58.21a
D_2	60.53a
D_3	45.44b
LS	**
CV%	**7.03**

LS = Level of significance, ** = Significant at 1% level of significance, CV = Co-efficient of variation. Here, D_1 =180 kg urea ha^{-1}, D_2 =162 kg urea ha^{-1} and D_3 =153 kg urea ha^{-1}. Figure in a column having similar letters meant statistically similar while dissimilar letters meant statistically dissimilar.