YIELD RESPONSE OF BROADCAST *AUS* RICE (*Oryza sativa* L.) TO NITROGEN VARIATIONS IN SOUTHWESTERN COASTAL REGION OF BANGLADESH

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ABSTRACT

Cropping in the southwestern (SW) coastal region of Bangladesh is completely different from other parts of the country. Generally, Fallow-Fallow-Transplanted (T) *Aman* is the main cropping pattern thus a vast area remains fallow during *Rabi* and *Kharif*-1 season. A new cropping pattern is emerging by incorporating broadcast (B) *Aus* rice during early summer, (*Kharif*-1), before monsoon (T. *Aman*) but the fertilizer requirement particularly N is not clearly defined. The present field study was done with T. *Aus* rice (var. BRRI dhan48) in a typical coastal soil in Pankhali, Dacope (a saline part of Agro-ecological Zone, AEZ 13), Khulna. There were 6 different levels of nitrogen treatment such as 0, 35, 52, 70, 87 and 104 kg ha^{-1}. Nitrogen rates had statistically significant effect on plant height, grain yield, straw yield, yield attributes (panicle length, number of grain $panicle^{-1}$, number of panicle m^{-2}, number of filled grain $panicle^{-1}$) and harvest index. At harvest, the highest tiller number (6.7), panicle length(19.3 cm), number of grain $panicle^{-1}$ (85.5), number of panicle m^{-2}(462.3), number of filled grain $panicle^{-1}$(71.1), 1000-grain weight (22.8 g) and grain yield (3.9 t ha^{-1}) were produced by 70 kg N ha^{-1}. Grain yield was not significantly increased with the application of N more than 70 kg ha^{-1}. The lowest values of almost all parameters were recorded from no N added treatment. The findings of the experiment revealed that 70 kg N ha^{-1}could be suggested for recommendation for maximum grain yield of B. *Aus* rice.

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CHAPTER I

INTRODUCTION

In Bangladesh, rice (*Oryza sativa* L.) is grown in three seasons: *Aus* (the spring season, from March/April to June/July), *Aman* (the monsoon season, from June/July to September/October) and *Boro* (the winter season, from November/December to April/May) (Emran et al., 2019). In *Aus* season, the area under cultivation is 1.3 million hectares, in *Aman* season the area is 5.63 million hectares and in *Boro* season the area is 4.78 million hectares during 2020-21,which produced 3.2, 14.4 and 19.8 million tons, respectively (BBS, 2021).

Aus rice is important for environment as it is less water requiring, cultivated in pre-monsoon rainfed conditions in Bangladesh. Broadcast *Aus* rice is established through direct broadcasting the seeds in April after the pre-monsoon shower and harvested in July to August (Shelley et al., 2016). Direct seeded broadcast rice would be an attractive alternative compared to that of transplanting particularly for south western coastal region on the case of fresh water scarcity (Bell et al. 2019), escalates labor rates (Farooq et al., 2011) and difficulties in seedling raising due to high saline water. Also transplanting cost is one of the major resource-consuming activities and it could be reduced through cultivating direct-seeded rice (DSR-*Aus*).

The coastal region is totally different from other parts of Bangladesh regarding salinity, cropping system, cultivation time, nutrient and organic matter status of the soil. The cultivable areas in coastal districts are affected with varying degrees of soil salinity. In Bangladesh about 1.06 million hectares of arable lands are affected by soil salinity. Over the last 35 years, salinity has increased to 26% within the country (SRDI, 2010). In the south western Bangladesh cropping intensity is low (~150%) and crop production are very much dependent on the traditional methods with single rice. About 78% of the agricultural land is used for T. *Aman* rice cultivation (BBS, 2017). Fallow- Fallow-T. *Aman* is the main cropping pattern in the south western coastal region. Recently some *Rabi* season crops after T. *Aman* (e.g., sunflower, maize, wheat and potato) have been introduced in southwestern (SW) coastal area in Pankhali, Dacope (a saline part of Agro-ecological Zone, AEZ 13), Khulna (Bell et al., 2019; Kabir et al., 2019).

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Aus rice grows in some pocket areas of southwestern region. A vast area in the south western region remain fallow during *Rabi* and *Kharif*-1 season especially which could be used for other crop cultivation including *Aus* rice after T. *Aman* (Bell et al., 2019) and it is now very much essential for our sustainable food security.

Aus rice is usually not cultivated by the farmers in the southwestern coastal Bangladesh. It might be due to some major constraints: lack of fresh water for seedling raising, main field preparation by puddling, soil dryness and cracking, saline water unsuitable for cropping. In this situation, direct seeding of *Aus* seed just after first (early) summer rain (in April-May) might open a window of rainfed *Aus* rice cultivation in this region (Bell et al. 2019). Most of the southwestern soils in Bangladesh are low in organic matter and deficient in nitrogen (Saha et al., 2012; Sarkar et al., 2016). There is no fertilizer recommendation for broadcasted *Au*s rice based cropping pattern in the southwestern coastal zone (FRG 2018). Among the major nutrient elements, nitrogen (N) is the most limiting nutrient for rice crop growth and yield which is required in higher amounts compared to other nutrients (Djaman et al., 2018). If a second crop is cultivated after T. *Aman* like *Aus* rice then optimum fertilizer would be necessary to be investigated. It is assumed that the gap exists between the amount of farmer's application and current recommendation of fertilizer including N.

The recommendation of fertilizer in FRG in Bangladesh is based on soil test basis (not based on plant response and soil test) and the soil samples collected from a large area of AEZ which might not represent the whole AEZ. For example, AEZ 13 includes saline and non-saline soils, different types of topography with different nutrient status (Emran et al., 2019) but the fertilizer recommendation is approximately similar. This fertilizer recommendation may not be suitable with the fertilizer requirement of crop in smaller zones (subzone) from where soil samples were not tested. Thus it is necessary to investigate the optimum rate of fertilizers including N for different areas in an AEZ. In a region with emerging cropping pattern, nutrient management is of prime importance as it comprises the major cost of crop cultivation and ecological importance. Considering these, the present study was carried out to study the effect of different N rates on high yielding rice variety BRRI dhan48 during *Aus* season in a typical coastal soil in Pankhali, Dacope, Khulna in the SW coastal region of Bangladesh.

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Objective

To evaluate the effect of Nitrogen rates on yield of *Aus* rice with a view to select and find out the optimum N rate in Pankhali, Dacope, Khulna in the south western coastal Bangladesh.

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CHAPTER II

REVIEW OF LITERATURE

2.1. Importance of rice

Rice (*Oryza sativa* L.) is the most important staple food crops for over half of the world's population and over 517.1 Mt of rice was produced globally in 2020 (FAO 2021). The average yield in Asia is low compared to global mean yield (Haider 2018). And, the possible way to meet this increases demand by improvement of rice yield per hectare (Liu et al., 2016). Population of Bangladesh is up surging by about two million every year and expected to increase by another 30 million over the following 20 years. Thus, Bangladesh will demand about 27.26 million tons of rice by 2020 to feed the increased mass of people. On the contrary, total arable land is supposed to be shrinked down to 10.28 million hectares from 11.25 million ha due to settlement and other causes (BRRI 2011).

Bangladesh is going to clinch third place in global rice production with an increased output of 36 million metric tons. In Bangladesh, about 75% of the total cropped area and over 80% of the total irrigated area is occupied by rice (BBS, 2021). Rice (*Oryza sativa*) is grown in Bangladesh's arable land during three cropping seasons: *Aus* (the spring season, from March/April to June/July), *Aman* (the monsoon season, from June/ July to September/October) and *Boro* (the winter season, from November/December to April/May) (Emran et al., 2019). In Bangladesh, the area under rice cultivation was 0.95 million hectares in *Aus* season, 5.56 million hectares in *Aman* season and 4.47 million hectares in *Boro* season during 2019-20), which produced 2.13 million tons, 13.6 million tons and 18 million tons respectively (BBS, 2021).

2.2 Role of nitrogen

Nitrogen (N) is the key element in the production of rice. Nitrogen management is essential for rice under aerobic culture as the nitrogen use efficiency range from 40 to 60 percent; application of nitrogen at right time is perhaps the simplest agronomic solution for improving the use efficiency of nitrogen (Ganga Devi et al, 2012). Nitrogen fertilization is the major agronomic practice that affects the yield and quality of rice crop, which requires as much as possible at early and mid tillering, stages to maximize panicle number and during reproductive stage to produce

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optimum spikelets per panicle and percentage filled spikelets (Sathiya and Ramesh, 2009). Most of the rice varieties are highly responsive to added nitrogen and they are not expected to produce their full yield potential without adequate fertilizers especially with nitrogen fertilizers. It promotes large leaf area index, long duration of photosynthesis, biomass accumulation, effective tillering, spikelets formation, high nutrient uptake and ultimately high crop productivity (Yoshida et al., 2006). An adequate supply of nitrogen to the crop plants during their early growth period is very important for the initiation of leaves and florets primordial. Rice uptakes large quantities of nitrogen to enhance growth, development, yields and grain quality.

To improve rice yield supplementation of N fertilizer under most agro-ecosystem has been suggested (Fageria and Santos, 2014). Nitrogen helps to increase rice productivity through improving leaf N concentration, photosynthetic rate, delaying leaf senescence, and increasing dry matter for grain filling. Moreover, N may also play great role in improving panicle size, grain weight and reducing spikelet sterility (Fageria, 2009). Application of N fertilizer in rice has also been reported to significantly increase the grain and straw yield N uptake and N use efficiency (Hassan et al., 2009).

Impact of nitrogen on growth characters

2.2.1 Plant height

Sikdar et al. (2018) reported that the highest plant height was produced with the application of100 kg N ha^{-1}.

Chaturvedi (2005) observed that application of nitrogen fertilizer increased the plant height. Theplant height 110.2 cm was recorded for urea.

Ahmed et al. (2005) observed that among 5 levels of N, 80 kg N ha^{-1} gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of N fertilizer application.

Salem (2006) reported that, the N levels had a positive and significant effect on growth parameters of rice plants in *Boro* season. Increasing N levels up to 70 kg ha^{-1} significantly increased plant height. The highest plant height at harvest was recorded about 92.81 cm when

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rice plants were fertilized with the highest N level of 70 kg ha^{-1}. On contrary, the lowest value of the plant height was recorded about 80.21 cm when rice plants received no N fertilizer.

Meena et al. (2003) reported that between two levels of N 100 and 200 kg ha^{-1}, application of 200 kg ha^{-1} significantly increased the plant height (127.9 cm) of rice and total number of tillers $hill^{-1}$ (16.3).

Lawal and Lawal (2002) observed that N (120 kg ha^{-1}) significantly increased plant height. A basal N application increased the plant height significantly.

Ebaid and Ghanem (2000) conducted a field experiment during the year of 1996-97 to find out the productivity and also the plant height of Giza 177 rice (*Oryza sativa*), N fertilizer was applied to the rice crop at the rate of 0, 96 and 144 kg N ha^{-1} in urea form and they found that increasing N level up to 144 kg ha^{-1} significantly increased plant height.

Sahrawat et al., (1999) found that nitrogen level significantly influenced plant height of rice. Increasing levels of nitrogen increased the plant height significantly up to 120 kg N ha^{-1}.

Thakur (1993) observed that the highest plant height of rice was obtained from 120 kg N ha^{-1} and the lowest one from the control.

Idris and Matin (1990) noted that plant height of rice increased up to 120 kg N ha^{-1} compared to the control and there after the height declined at 140 kg N ha^{-1}.

2.2.2. Tillering pattern

BRRI (2008a) conducted an experiment to study some promising lines with BRRI modern rice varieties to different N levels viz. 0, 30, 60, 90, 120 and 150 kg N ha^{-1}. It was reported that tiller production with N @ 120 kg ha^{-1} produced significantly higher tiller than those of lower N levels.

BRRI (2006) reported that the maximum tillers $hill^{-1}$ (10.2) was produced with 120 kg N ha^{-1} compared to 90 and 0 kg N ha^{-1} application.

Wang et al. (2002) reported that the tiller number increased with increasing N levels.

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Lawal and Lawal (2002) carried out 3 field experiments during the rainy season of 1996, 1997 and 1998 in Nigeria to evaluate the growth and yield response of lowland rice to varying N rates and placement methods. The treatment consisted of 4 N rates (0, 40, 80 and 120 kg ha^{-1}) and 2 fertilizer placement method of (deep and surface placement). They found that application of 80 kg N ha^{-1} significantly increased the number of tillers $hill^{-1}$.

Munnujan et al. (2001) conducted a field experiment at Gazipur in 1993 to determine the effects of N fertilizer and planting density on growth and yield of long grain rice. Tillers $plant^{-1}$ increased linearly with the increase in N fertilizer levels.

2.2.3. Total dry matter production

Sing and Modgal (2005) noted that dry matter accumulation (DMA) and concentration and uptake of N increased with increasing level of N at all the stages of crop growth. A field test with the super hybrid rice (SHR) combination Liangyoupeijiu was conducted by Tang et al. (2003) in Changsha, Hunan, China. Nine treatments were used, including 0, 60, 120, 180, 240, 180, 130, 225 and 160 kg N ha^{-1}. They reported that higher N fertilizer application amount ensured a higher leaf area index.

Fu et al. (2000) conducted a field experiment in Zhejiang Province, China to evaluate the N fertilizers (0, 100, 150, 180, 225, 270, and 300 kg N ha^{-1} as urea, two-thirds top-dressed as basal and one third top dressed 7 days after transplanting, on dry matter and N partitioning in hybrid rice 518. They reported that higher N applications significantly increased dry matter partitioning of leaf at the vegetative stage. Partitioning of dry matter to leaves decreased as the N concentration in the leaves decreased. Leaf partitioning of absorbed N, compared to dry matter, was higher and varied little during early vegetative growth, but varied greatly from panicle initiation onwards, probably due to competition for N among leaves, stem and the developing panicle.

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A field experiment was conducted by Geethadevi et al. (2000) in Karnataka, India to determine the effect of different N rates (0, 50, 100 and 150 kg N ha^{-1}) and spacing (15 cm x 10 cm or 20 cm x 10 cm) on the growth and yield of hybrid rice. Among N rates, treatment with 150 kg N ha^{-1} recorded the highest values for total dry matter per plant (57.08 g).

Ahmed et al. (2005) who observed the significant effect of nitrogen on total dry matter (t ha^{-1}) of rice

2.3 Effect on yield contributing character

2.3.1 Panicle length

Islam et al. (2008) conducted an experiment to study the effect of N and number of seedlings per hill on the yield and yield components of T. *Aman* rice (BRRI dhan33). They noted that panicle length, number of grain $panicle^{-1}$ increased with the application rate of N up to 100 kg ha^{-1} and then declined.

Singh and Shivay (2003) found that increasing levels of N significantly increased the panicle length.

Meena et al. (2002) observed that increase in N fertilizer application rate enhanced length and weight of panicles of hybrid rice.

Ebaid and Ghanem (2000) indicated that increasing N levels up to 144 kg N ha^{-1} significantly increased panicle length of rice.

El-Batal et al. (2004) showed that increasing N rate from 50 to 80 kg ha^{-1} significantly increased panicle length.

Sarkar et al. (2001) conducted a field experiment during the *kharif*1995 in West Bengal, India to evaluate the performance of 3 rice cultivars (IET 12199, IET 10664 and IET 15914) treated with 5 different N fertilizer levels (0, 40, 80, 120 and 160 kg ha^{-1}). IET 12199, treated with 80 kg N ha^{-1} gave the highest values for panicle length (25.77 cm); IET 10664 and IET 15914 also performed well.

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Freitas et al. (2001) conducted a field experiment in Mococa, Sao, Paulo, Brazil during 1997-98 and 1998-99 to evaluate the response of three new rice cultivars (IAC- 101, IAC-102 and IAC 104) grown under irrigated conditions N fertilizer was applied as urea (at the rate of 0, 50, 100 and 150 kg ha^{-1}) 33% at seedling transplantation and 33% at 20 and 40 DAT. They found that panicle length of three cultivars was significantly affected by N treatments.

2.3.2 Filled grains $panicle^{-1}$ and unfilled grains $panicle^{-1}$

BRRI (2006) found that increasing level of N increased the number of spikelet $panicle^{-1}$of rice and the highest number of spikelet $panicle^{-1}$ (82.2) was obtained with 120 kg ha^{-1} compared to 90 and 0 kg ha^{-1} urea respectively.

Lang et al. (2003) found that the increase in N fertilizer application rate enhanced grains per panicle, effective panicles per plant and total florets per plant.

Meena et al. (2002) noted that increase in N fertilizer application rate enhanced number of grains and filled grains of hybrid rice.

Ehsanulla et al. (2001) pointed out that the N level of 125 kg ha^{-1} produced maximum number of grains $panicle^{-1}$.

2.3.3 1000 grain weight

Chopra and Chopra (2004) showed that N had significant effects on yield attributes such as plant height, panicle $plant^{-1}$and 1000-grain weight. Cumulative effect of yield attributing and nutrient characters resulted in significant increase in seed yield at 120 kg N ha-^{1}over 60 kg N ha^{-1} and the control.

Maitti et al. (2003) reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield (by 76.2%), number of panicles (by 109.00%), number of filled grains per panicle (by 26.2%) and 1000-grain weight (5.80%) over the control.

Meena et al. (2002) reported that increase in N fertilizer application rate increased 1000 grain weight of hybrid rice.

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Rahman et al. (1985) noted that there was a little relationship between nitrogen and weight of 1000 grains of rice.

2.3.4 Grain yield and straw yield

Munnujan et al.(2001) reported that the highest grain yield (3.8 t ha^{-1}) was obtained at 180 kg N ha^{-1}, which was similar to the yield obtained at 80 kg N ha^{-1} (3.81 t ha^{-1}).

Singh et al. (2000) stated that each incremental dose of N gave significantly higher grain and straw yields of rice over its preceding dose. Consequently the crop fertilized with 100 kg ha^{-1} gave the maximum grain yield (2647 kg ha^{-1}).

Chopra and Chopra (2000) reported that the application of N at the rate of 80 kg N ha^{-1} improved all the yield attributes compared with control treatment.

Neelam and Nisha (2000) stated that significant linear increase in seed yield was recorded up to 80 kg N ha^{-1} and thereafter a marginal reduction in seed yield was observed at 120 kg N ha^{-1}. Straw yield increased up to the highest level of N. They recommended 98.5 kg N ha^{-1}.

BRRI (2008b) conducted an experiment on the title of response of MVs and hybrid entries to added N in a rice cropping pattern. Six N doses 0, 40, 80, 120, 160 and 120 kg N ha^{-1} were tested and resulted that grain yield of hybrid responded up to 120 kg N ha^{-1}.

A study was conducted by Ingale et al. (2005) to determine the effects of seedling ages at transplanting (25, 40 and 55 days), number of seedlings per hill (one or two) and N rates (50, 100 and 150 kg ha^{-1}) on the yields of Sahyadri rice hybrid. They found that the application of 150 and 100 kg N ha^{-1} resulted in significantly higher yields than treatment with 50 kg N ha^{-1}.

A field experiment was conducted by Upendra et al. (2004) at Pusa, Bihar, India to evaluate two newly developed rice hybrids (KHR2 and DRRH1) and one local control (*Boro* 5) growth under 10 different N-potassium (NK) fertilizer levels. Data were recorded for plant height, effective tillers m^{-2}, panicle length, test weight, grain yield, straw yield, harvest index and benefit: cost ratio. Both rice hybrids performed better than the local cultivar. Yield and related characters increased with increasing fertilizer levels up to 150 kg N ha^{-1} and 80 kg K ha^{-1}.

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A study was conducted by Verma et al. (2004) in Madhya Pradesh, India to investigate the effect of planting date (20 July; and 5 and 20 August) and N rates (50, 100 and 150 kg ha^{-1}). They revealed that N at 100 and 150 kg ha^{-1} resulted in the highest yield.

Singh and Shivay (2003) found that increasing levels of N significantly increased the grain and straw yields.

Maitti et al. (2003) reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield.

A field experiment was conducted by Devasenamma et al. (2001) in Andhra Pradesh, India to study the performance of rice hybrids (APHR-2, DRRH-1, MGR-1, TNRH-16 and NLR-33358) at various N fertilizer rates (0, 60, 120 and 180 kg ha^{-1}). The highest values for yield and yield components were obtained with 180 kg N ha^{-1}.

2.3.5. Harvest index

Khatun et al., (2015) found that the main effect of nitrogen sources (N) was highly significant (0.05) for harvest index. In both BRRI dhan28 and BRRI dhan29 the HI varied from 0.44 to 0.46. The N control plots gave the lowest HI in both the varieties. The application of N increased HI slightly.

Sarkar et al., (2001) obtained the nitrogen response of a Japonica and an Indica rice variety with different nitrogen levels viz. 0, 40, 80 and 120 kg N ha^{-1}. They observed that application of nitrogen increased grain and straw yields significantly but harvest index was not increased significantly.

Dwivedi (1997) noticed that application of nitrogen significantly increased the growth yield and yield components grain yield, straw yield as well as harvest index with 60 kg N ha^{-1}.

2.4 Research area and nitrogen

The coastal belt of Bangladesh consists of 19 districts, which covers 32% of the country accommodates more than 35 million people (Huq and Rabbani, 2011). Salinity affected a recorded 105.6 million hectares during 2009. Among these affected areas, around 2.5 million

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hectares of low-lying coastal lands represents 0.9 to 2.1 salinity level (SL) in Bangladesh (Haque et al., 2006). Over the last 35years, salinity has increased around 26 percent in the coastal region of Bangladesh (Mahmuduzzaman et al., 2014). As a result, soil and water salinity are considered a major constraint to agricultural production. Estimates indicate that, more than two hundred million tons of rice is lost every year due to environmental stresses, diseases and pest incidents (Chen and Murata, 2002). Among the environmental stresses, water stress is a major yield restraining factor of rainfed rice.

Most of the lands in southwest region are kept fallow in the summer or pre-monsoon hot season (March-early June) and autumn or post-monsoon season (October- February) because of soil salinity, lack of good quality irrigation water and late draining condition. In the recent past, with the changing degree of salinity of southwest coastal region of Bangladesh, rice production becomes very risky and crop yields, cropping intensity, production levels of rice and people's quality of livelihood are much lower than that in the other parts of the country (Kabir et al. 2019).

N deficiency is a major problem in many Asian and African countries, as well as in South America. Estimates suggest that ~50 % of agricultural soils are deficient in N. The two main reasons for this are (i) insufficient application of N in the form of N fertilizer or manure and (ii) N-fixing soil properties which render N unavailable to plants even if it is present in sometimes large amounts. Nitrogen imbalances in the world, with too much N in some countries and too little or inaccessible N in others (Mac Donald et al. 2011) will require different measures and breeding strategies.

Nitrogen is often deficient in sandy soils with low organic matter content, calcareous /saline/alkaline soils, volcanic ash soils or acid upland soils with high N fixation capacity; peat soils and acid sulfate soils high in active iron and aluminum causing decrease in crop yields.

Flooded soils exhibit a greater capacity to supply plant available nitrogen than non-flooded soils (Dobermann and Fairhurst, 2000). Crops grown on flooded soils may not show a response to nitrogen applications, while the same crop grown on the same soil when dry may exhibit deficiencies (De Datta, 1981). Although the increase in availability of N is regarded as a benefit of flooding rice soils, the effect on rice growth may not be appreciable in acid clays high in active Fe (IRRI, 1985). The beneficial effect of flooding on N depends on the intensity of redox condition of submerged soil and Fe content (De Datta, 1981).

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2.5 Importance of *Aus* rice for coastal belt

Among the rice cultivating seasons in Bangladesh viz. *Aus, Aman* and *Boro*, *Aus* rice is mostly cultivated under rainfed condition during April to August where June to July are most important as the crop passes its reproductive stage during this time yet the rainfall is very erratic in nature. After the 1980s, *Aus* production slowly began to lose priority to the farmers as they shifted to irrigated *Boro* rice cultivation due to its higher yield (BRRI 2011). The Government of Bangladesh has given top priority for increasing the area and production of *Aus* rice to reduce the pressure on electricity for irrigation needed for *Boro* rice production during dry season. Compared to *Boro, Aus* requires less irrigation and the plan is to cut dependency on the underground water for irrigation and arrest the fall in the water level in the aquifer. Water stress reduces the grain filling percentage and grain weight, resulting in a significant decrease of grain yield by 11.6% to approximately 14.7%. *Aus* rice requires less number of days to mature compared to *Aman* and *Boro*. So, it has the capability to escape late season drought (BRRI 2011). *Aus* rice in this regard can create scope by scaling up production and shed dependency on the underground water (UNB 2017). Therefore, prearranged the large area under rainfed rice cultivation system and the increasing prevalence of drought stress in a wide range of cultivation systems because of declining water table depths, improving the *Aus* rice varieties has a large potential for helping to achieve sustainable rice production. But the main drawback is the average yield of *Aus* rice (2.16 t ha^{-1}) which is lower than *Aman* and *Boro* rice (BBS 2013). Using the latest high yielding varieties of transplanted *Aus* rice along with improved cultivation techniques might be the best possible options to meet this productivity gap of *Aus* rice.

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CHAPTER III

MATERIALS AND METHODS

This chapter represents a brief description of location, climate, soil, crop, experimental design, treatment, cultural operations and statistical analysis of collected data.

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted in Pankhali, Dacope, Khulna. The field experiment was conducted in Agro-ecological Zone (AEZ) 13, i.e. Gangetic Tidal Floodplain and ($22^0$38'00"N latitude and $89^0$30'12" E longitudes) at an elevation of ~3 meter from sea level.

3.1.2 Period of experiment

The experiment was conducted in *Aus* season, during May 2019 to September 2019.

3.1.3 Soil

The experimental field was medium low land with clay dominated soil (soil texture: clay). The soil texture ranged from silty clay at 0-30 cm depth to clay at 30-60 cm and the soil was almost neutral, pH-7.3. Among the tested nutrients organic matter was medium. Except N (0.12%) other nutrients were found high to very high level.

3.1.4 Climate

The experimental field was characterized by sub-tropical climate with moderately high temperature and heavy rainfall during the *kharif* season (April to October) and low rainfall with moderately low temperature during the *Rabi* season (November to March) (Bell et al., 2019). The meteorological data (temperature and rainfall) for the period of May 2019 to August 2019 recorded from the weather station, Khulna graphically presented:

Temperature

The temperature during the growing period of 2019 ranged from 22.4-37.8° C (Fig.1). The average monthly maximum temperature of May 2019, June 2019, July 2019 and August 2019 was 36.2.0°C, 35.2°C, 33.7°C and 33.1°C, respectively while the minimum monthly average temperature was 26.7°C, 27.2°C, 27.1°C and 26.7°C, respectively.

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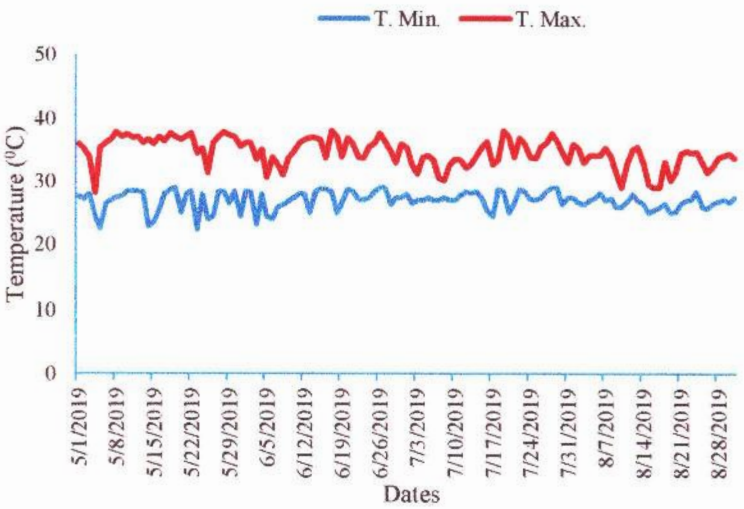

Figure 1. Maximum and minimum temperature pattern during the growing period (May -August, 2019) in the experimental area from the weather station, Khulna.

Rainfall

The measurement of rainfall during the experiment shows that there was insufficient rainfall during the experiment (Figure 2). The maximum rainfall was 74 cm and minimum zero. There was not sufficient rainfall before the experiment was laid down.

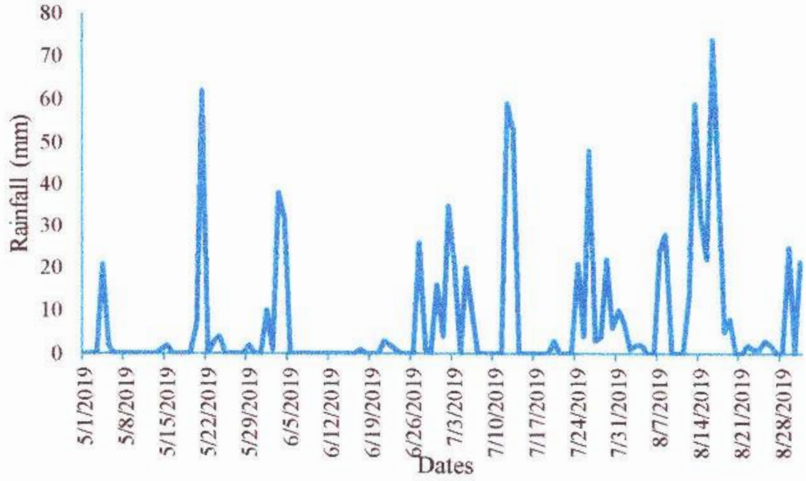

Figure 2. Rainfall pattern during the growing period (May '19-Aug '19) in the experimental area from the weather station, Khulna.

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3.2 Experimental design and treatment

The experiment was laid out in Randomized Complete Block Design (RCBD) with six treatments and three replications. The total experimental plots were 18 and the size of individual plot was 10 m^2 (5.0 m x 2.0 m). Plot to plot distance was maintained 0.5 m and block to block distance was 1.0 m. Six nitrogen (N) doses were the treatments as follows:

Nitrogen rates (kg ha^{-1}):

N_0= Control

N_1= 35 (50% of Recommended dose)

N_2= 52 (75% of Recommended dose)

N_3= 70 (100% of Recommended dose for T. *Aus* rice) (for BRRI dhan48)

N_4= 87(125% of Recommended dose)

N_5= 104 (150% of Recommended dose)

Layout of the experimental field is presented in appendix 4.

3.3 Field preparation

The experimental land was ploughed on 9 May 2019 with the help of a tractor; later the land was irrigated and prepared by three successive ploughings and cross-ploughings. All kinds of weeds and residues of the previous crop were removed of the field after tillage. The field was divided into unit plot size according to the design. Final layout of the experiment was done at 12th May.

3.4 Fertilizer application

The quantity of fertilizer needed for each treatment was worked out by following standard procedure. Nitrogen, phosphorus, and potassium were applied in the form of urea, triple super phosphate (TSP) and muriate of potash (M_OP). Again calcium and zinc were applied in the form of gypsum and zinc sulphate.

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Basal dose of fertilizer (half of urea and full dose of other fertilizers) were applied at the time of final land preparation on 13th May, 2019 and remaining half of urea was applied at 35 days after sowing (DAS) on 20thJune. Other fertilizers were applied according the recommendation of the BRRI (2008) for the *Aus* rice of the AEZ 13.

They were (kg ha^{-1}): TSP-10.5 kg, MoP-36 kg, $ZnSO_4$-1.2 kg and Gypsum-7 kg

3.5.1. Planting materials

BRRI dhan48, a high yielding variety of *Aus* rice (this a *Boro* rice variety, also can be cultivated in *Aus* season) was used as test crop in this experiment. The variety was released by Bangladesh Rice Research Institute, Joydebpur; Gajipur. The life span of this variety is about 110 days' in *Aus* Season. Grain yield is about 5.5 ton ha^{-1}

3.5.2. Seed collection and Seed sowing

Seeds of BRRI dhan48 were collected from BRRI (Bangladesh Rice Research Institute). Quality seeds are selected. The time of seed sowing in main field was 15th May. Direct seeding in line was done with 25 cm row spacing. Seed rate was 22.5-30 kg ha^{-1}.

3.5.3. Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from 0-15 cm soil depth. The samples were collected with the help of an auger from different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. After the collection of soil samples, the plant roots, leaves etc were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis. The soil samples were analyzed from the SRDI, Daulatpur, Khulna.

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3.6 Intercultural operation

Intercultural operations were done as per recommendation.

3.6.1 Thinning

Thinning was done at 30 DAS and 45 DAS to avoid competition for light, nutrient and water etc.

3.6.2 Weeding

Hand weeding was done at 20, 40 and 60 DAS to avoid crop weed competition.

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3.6.3 Plant protection

Pest management was done properly. Insecticide Nitro 505 EC (chloropiriphos + Cyprermethrin) was used 1ml L^{-1} at 45 DAS and 70 DAS to free from diseases attack. But the field was always under a careful observation.

3.6.4 Irrigation

Two irrigations were provided to the field. First Irrigation on 15-05-19 (at sowing time) and second Irrigation, 20-06-19 (at vegetative stage) by surface method from the nearer pond and the EC of the water was 0.8 ds m^{-1}.

3.7 Harvesting and threshing

The crop was harvested when 80–90% of the grains turned golden yellow in color. The crop was harvested on 1 September, 2019. Threshing was carried out manually. The grains were cleaned. The grains and straw was oven dried. Finally, grain and straw yields of each treatment was determined and converted to t ha^{-1}.

3.8 Data collection:

Five hills from each plot were selected at random and tagged for the purpose of recording various observations.

3.8.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of 30, 45, 60, 75, 90 DAS and at harvest. Data were recorded from five plants of each plot carefully. The height was measured from the ground level to the tip of the tiller.

3.8.2 Number of tillers plant^{-1}

The number of tillers plant^{-1}was recorded at the time of 30, 45, 60, 75, 90 DAS and at harvest. Data were recorded carefully by counting all tiller number from five plants of each plot.

3.8.3 Number of effective tiller (m^{-2})

Panicles were counted 1 m^2 area from each treatment and the average panicle m^{-2} was calculated.

3.8.4 Dry matter plant^{-1} (g)

Five plants were uprooted from each unit plot at harvesting time; oven-dried 70° C for 72 hours and weighed to calculate the total dry matter accumulation.

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3.8.5 Panicle length (cm)

Panicle length was measured from five randomly selected panicle separately from each plot.

3.8.6 Number of grains panicle^{-1}

The total number of grains was collected from randomly selected 5 plants of a plot on the basis of grain in the spikelet and then average number of grains panicle^{-1} was recorded.

3.8.7 Number of filled grains Panicle^{-1}

The total number of filled grains was collected from randomly selected 5 plants of a plot on the basis of filled grain in the spikelet and then average number of filled grains panicle^{-1} was recorded.

3.8.8 Number of unfilled grains Panicle^{-1}

The total number of unfilled grains was collected from randomly selected 5 plants of a plot on the basis of unfilled grain in the spikelet and then average number of unfilled grains Panicle^{-1} was recorded.

3.8.9 Weight of 1000 grains (g)

One thousand grain were counted randomly from the total cleaned harvested grain of each individual treatment and then weighed in grams and recorded.

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

Grains obtained from each treatment plot were sun-dried and weighed carefully. The dry weight of grains from 1 m^2 area to the respective grain yield per m^2 and converted to t ha^{-1}.

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

Straw yield was obtained in the same way of grain yield, sun-dried and weighed carefully. The dry weight of straw of 1 m^2 area to the respective straw yield m^2 and finally converted to t ha^{-1}.

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

Biological yield is the summation of grain yield and straw yield. It was calculated by using the following formula:

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

3.8.13 Harvest index (%)

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

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Harvest index was calculated by using formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} X\ 100$$

3.9 Statistical analysis

The collected, calculated and recorded data on different parameters were compiled and statistically analyzed following the analysis of variance techniques (one-way ANOVA) by using 'Statistix 10'.The significant differences among the treatment means were compared following all pair wise comparison by least significant different (LSD) at 5% level of significance and the mean differences were adjusted with Duncan's New Multiple Ranges Test (DMRT).

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CHAPTER IV

RESULTS AND DISCUSSION

The result of the experiment was presented by evaluating the growth, yield attributes and yield of B. *Aus* rice (BRRI dhan48) in response to nitrogen rates.

4.1.1. Plant height (cm)

Different nitrogen doses affected the plant height significantly (p<0.01) at different days after sowing (DAS) and at harvest (Table 1).

Table1. Effect of nitrogen dose on plant height of B. *Aus* rice (BRRI dhan48)

Nitrogen doses (kg ha^{-1})	Plant height (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
0	20c	29.5c	42.1c	54.2c	66.1c	65c
35	26.4ab	34.1b	48.5b	63.7ab	74.8b	73.5b
52	27.5ab	36.2ab	52.4ab	65.1ab	79.6ab	79ab
70	28.9a	38.2a	55.4a	68.9a	83.7a	83a
87	25.8ab	36.8ab	52.1ab	64.5ab	79.7ab	79.1ab
104	25.2b	34.8b	50.76ab	63.2b	78.2ab	77.1ab
LS	**	**	**	**	**	**
CV (%)	6.8	5.19	6.6	4.55	4.63	4.83

In a column, same letter indicates the means are statistically similar.LS indicates level of significance ** and * indicate significant at 1% and 5% levels, respectively. NS indicates non-significant, CV indicates Co-efficient of variation.

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Plant height increased progressively up to 90 DAS. The tallest plants were produced in all treatments at 90 DAS. At all the recorded days' highest value of plant height was observed from 70kg ha^{-1}. Later at harvest also the maximum plant height (83.7 cm) was obtained from application of 70 kg N ha^{-1} (N_3) which was statistically similar with N_2, N_4 and N_5. Lowest plant height was recorded in control.

4.1.2. Number of tillers plant^{-1}

The data pertaining to the number of tillers per plant at different stages of growth was significantly influenced (p<0.001) by various doses of nitrogen are presented in table 2.

Table 2. Effect of nitrogen variation on tiller number of B. *Aus* rice (BRRI dhan48)

Nitrogen doses (kg ha^{-1})	Tiller Number plant^{-1}					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
0	1.5b	3.1c	3.7b	3.3c	3.1c	2.9c
35	2.1ab	4.5b	5.3ab	3.9b	3.8b	3.5bc
52	2.2a	4.8ab	5.8a	4.3ab	4.0ab	3.9ab
70	2.7a	5.5a	6.7a	4.8a	4.6a	4.5a
87	2.1ab	4.5b	5.7a	4.4ab	4.5a	4.3a
104	2.1ab	4.3b	5.6a	4.2ab	4.4ab	4.2a
p	<0.05	<0.001	<0.05	<0.01	<0.01	<0.01
LS	*	***	*	**	**	**
CV (%)	18.95	8.74	18.43	8.39	8.66	9.15

In a column, same letters indicate statistically similar and different letter indicate statistically dissimilar results among the treatments. ** = Significant at 1% level of significance, * = Significant at 5% level of significance, NS = Non significant, LS = Level of significance, CV = Co-efficient of variation

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In all treatments, number of tillers increased and attained a maximum value at 60 DAS, which was considered as active tillering stage. After that, number of tillers decreased towards maturity due to tiller mortality. At maximum tillering stage highest number of tillers produced by 70 kg N which was statistically similar to the rest of the treatments except control. At harvest maximum number of tiller was observed with70 kg N ha^{-1} which was statistically similar to N_2, N_4 and N_5. Lowest number of tiller was recorded in control.

4.1.3. Total dry matter (t ha^{-1})

Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. It is the summation of grain yield and straw yield. Total dry matter differed significantly due to the different nitrogen treatments (Figure 3). Application of treatment N_5 produced the highest total dry matter (8.36 t ha^{-1}) which was statistically similar to treatment N_2 (8.24 t ha^{-1}), N_3 (8.22 t ha^{-1}) and N_4 (7.92t ha^{-1}). The lowest total dry matter (4.76 t ha^{-1}) was recorded from control.

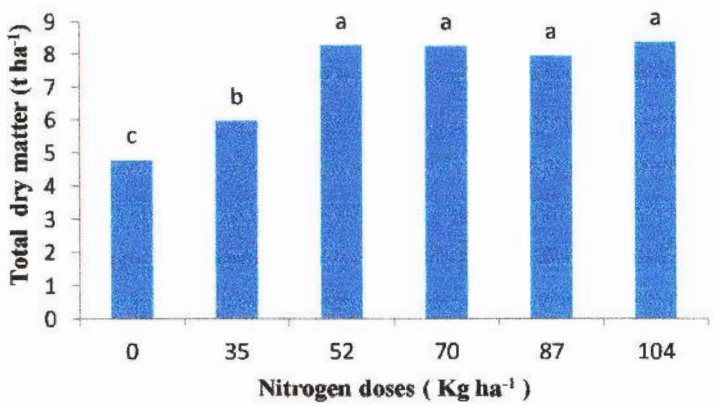

Figure 3. Effect of Nitrogen variation on total dry matter production of B. *Aus* (BRRI dhan48)

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4.1.4. Effective tiller (m^{-2})

Application of different rates of nitrogen had significant ($p \leq 0.01$) effect on production of number of panicle m^{-2}. The findings showed an increasing trend of effective tiller m^{-2} with the increase in nitrogen doses and rate of increase was up to 70 kg N ha^{-1} after that the increasing rate was decreased. However, it was recorded that 70 kg N ha^{-1} (N_3) produced the maximum number (462.33) of panicle m^{-2} and was statistically similar with the result recorded from $N_2$and N_4 while the lowest number of effective tiller m^{-2} (337.3) was found in control where nitrogen was not applied.

4.1.5. Panicle length (cm)

Significant variation ($p \leq 0.01$) was found regarding panicle length due to different nitrogen doses (Table 3). The maximum panicle length (19.3 cm) was obtained from 70 kg N ha^{-1} (N_3) that was statistically similar with $N_{2,}$ N_4 and N_5 while the minimum panicle length (16.21 cm) was found in N_0 where nitrogen was not applied.

4.1.6. Number of grain panicle^{-1}

Application of different rates of nitrogen had significant ($p \leq 0.01$) effect on production of number of grain panicle^{-1} (Table 3). The findings showed an increasing trend of number of grain panicle^{-1} with the increases in nitrogen doses up to 70 kg N $ha^{-1}$and it was statistically similar to rest of the treatments except control. The lowest number (53.67) of grain panicle^{-1} was produced from control treatment (N_0) as expected.

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4.1.7. Number of filled grains panicle^{-1}

From the table 3 it was observed that there was a statistical variation in number of filled grains panicle^{-1} due to N fertilizer. Results showed that the maximum number of filled grains panicle^{-1} (67.9) was obtained from 70 kg N ha^{-1} (N_3) and showed statistically similar results with N_1, N_2 and N_4 .The lowest (37.4) was produced in control method (N_0).

4.1.8. Number of unfilled grains panicle^{-1}

Nitrogen had a significant influence on the unfilled grains panicle^{-1} (Table 3). The figure showed that the highest (18.73) number of unfilled grain was obtained due to the application of treatment N_5 followed by treatment N_0 (16.2) and N_4 (16.1).The lowest (11.3) number of unfilled grain panicle^{-1} was obtained in N_1 which was statistically similar to N_2 and N_3.

4.1.9. 1000 grain weight (g)

Effect of nitrogen on 1000 grain weight was not statistically significant (Table 3). Numerically the maximum weight (22.8 g) was found in 70 kg N ha^{-1} (N_3) which was statistically similar with all the treatments and minimum (20.9 g) was obtained from 35 kg N ha^{-1} (N_1).

4.1.10. Grain yield (t ha^{-1})

Grain yield (t ha^{-1}) showed significant variation (1% level of significance) by different rates of nitrogen (Figure 4). The maximum grain yield (3.91t ha^{-1}) was recorded from 70 kg N ha^{-1} (N_3) which showed statistically similar results with 87 kg N ha^{-1}and 104kg N ha^{-1}whereas the minimum (1.9 t ha^{-1}) was found in 0 kg N ha^{-1} (N_0).

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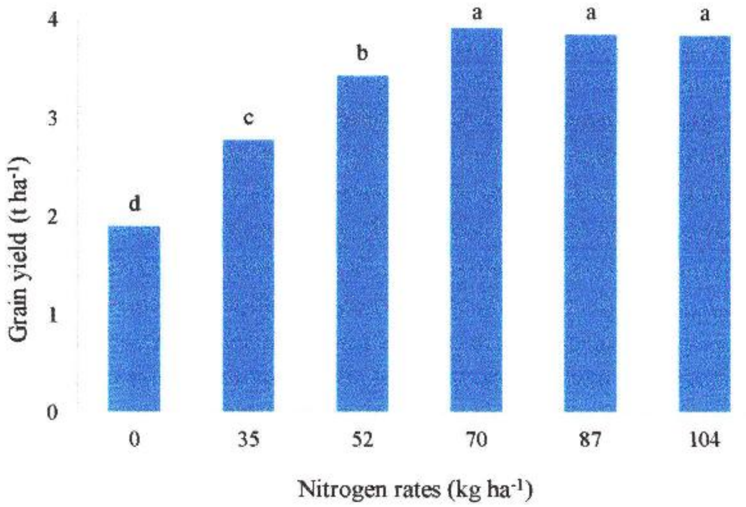

Figure 4. Effect of Nitrogen variation on grain yield of B. *Aus* rice (BRRI dhan48)

(LSD value o.o5)

4.1.11. Straw Yield (t ha^{-1})

The straw yield of rice at different rates of nitrogen showed significant variation (p<0.01). The straw yield at different levels of nitrogen application ranged from 2.37 t ha^{-1} to 4.52 t ha^{-1} (Table 3). The maximum straw yield (4.52 ton ha^{-1}) was obtained from application of 104 kg N ha^{-1} (N_5) which was statistically similar with all treatments exceptN_0. The lowest straw yield (2.55t ha^{-1}) was obtained fromN_0.

4.1.12. Harvest Index (%)

The influence of nitrogen doses on harvest index was significant (p<0.05). The harvest index ranged from (40.11%) to (47.52%). The highest value (47.52%) was obtained from 70 kg N ha^{-1} (N_3) and the lowest value (40.11%) was obtained from 35 kg N ha^{-1} (N_1) (Table 3).

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Table 3. Effect of nitrogen variation on yield and yield components of B. *Aus* rice (BRRI dhan48) grown in a southwestern coastal soil of Bangladesh.

Nitrogen rates (kg ha^{-1})	Effective tiller (m^{-2})	Panicle length (cm)	No. of grain panicle^{-1}	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000 Grain Weight (g)	Straw Yield (t ha^{-1})	Harvest Index (%)
0	337.33c	16.20c	53.66b	37.40c	16.26ab	21.86	2.37b	44.51a
35	415.00b	18.05b	72.53a	61.20ab	11.33c	20.90	4.16a	40.11b
52	425.67ab	18.83ab	81.80a	67.93ab	13.86bc	21.67	4.11a	45.52a
70	462.33a	19.30a	85.53a	71.06a	14.46bc	22.83	4.32a	47.52a
87	420.33ab	18.46ab	75.40a	59.33ab	16.06ab	21.85	4.45a	46.48a
104	411.67b	18.23ab	73.66a	54.93b	18.73a	20.96	4.52a	45.94a
p	<0.01	<0.01	<0.01	<0.01	<0.01	0.39	<.01	<0.05
LS	**	**	**	**	**	NS	*	*
CV (%)	5.74	3.51	10.14	13.19	11.98	5.28	6.59	4.42

In a column, same letter indicate statistically similar and different letter indicate statistically dissimilar results among the treatments. ** = Significant at 1% level of significance, * = Significant at 5% level of significance, NS = Non significant, LS = Level of significance, CV = Co-efficient of variation

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4.1.13. Regression analysis: Effective tiller and grain yield

The strong positive linear relationship was observed between effective tiller and grain yield (p<0.01) with a R^2value of 0.73with the equation of y = 0.0167x – 3.5944depicting that 73% change in grain yield could be explained by changing effective tiller (Figure. 5). The relationship also showed that with increase of effective tiller 337.33 to 462.33grain yield increased from 1.9 to 3.91.

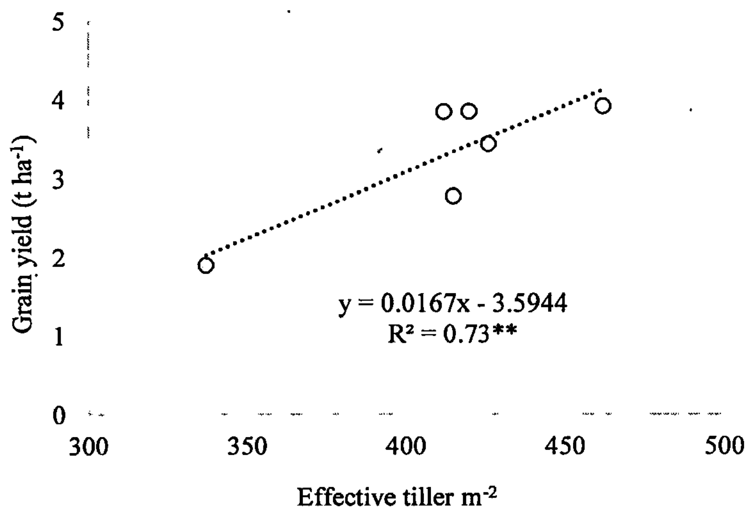

Figure 5. Functional relationships between grain yield (t ha^{-1}) and effective tiller m^{-2}

4.1.14. Regression analysis: Filled grain panicle^{-1} and grain yield

The strong positive linear relationship was observed between filled grain panicle^{-1} and grain yield (p<0.01) with a R^2 value of 0.55 with the equation of y = 0.0499x + 0.3578 depicting that 55% change in grain yield could be explained by changing filled grain (Figure 6). The relationship showed that with increase of filled grain 37.40 to 71.06 grain yield increased from 1.9 to 3.91.

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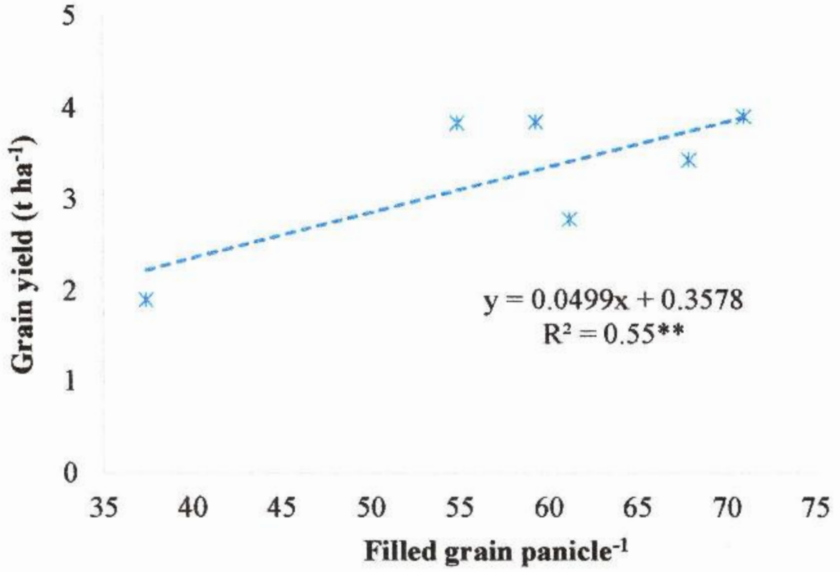

Figure 6. Functional relationships between filled grain panicle^{-1}and grain yield (t ha^{-1})

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Discussion

Addition of N fertilizer from 0 to104 kg ha^{-1} had significant effect on most of the studied parameters including yield attributes (panicle length, number. of grain $panicle^{-1}$, number of filled grain $panicle^{-1}$and number of unfilled grain $panicle^{-1}$) and grain yield. Grain yield was significantly influenced (1% level of significance) between 0 and other N rates due to variation in some yield attributes which increased significantly and consequently 70 kg N ha^{-1} treatment ultimately resulted in highest yield of grains. Nitrogen may also play great role in improving panicle size, grain weight and reducing spikelet sterility (Fageria, 2009). Application of N fertilizer in rice has also been reported to significantly increase the grain and straw yield N uptake and N use efficiency (Hassan et al., 2009).

The highest grain yield was obtained from 70 kg ha^{-1} which was statistically similar with N_4 and N_5 and the lowest grain yield was obtained from the 0 kg N ha^{-1} treatment. The soil analysis report of this field showed that soil contained 0.124% N (1-15 cm soil depth) which is designated as low amount of N in soil for AEZ 13 (FRG, 2018). As the fertilizer recommendation in FRG of Bangladesh is based on the soil test only, not based on the plant response. Nitrogen recommendation for T. *Aus* rice is available in the FRG 2018 but not for B. *Au*s rice in the southwestern coastal zone (FRG 2018). In FRG (2018) N rates recommended for T. *Aman* in fallow-fallow-T. *Aman* cropping pattern of saline soil of AEZ 13 is 70 kg N ha^{-1}.The current study suggests that the recommended dose of N fertilizer 70 kg ha^{-1} for transplanted *Aman* and T. *Aus* is also suitable for B. *Aus* in the area.

In short, *Aus* rice cultivation is possible in *Kharif*-1 season by broadcasting the seed just after starting of summer rainfall is possible with N rate 70 kg ha^{-1} in the SW coastal region of Bangladesh. The suggested 70 kg N ha^{-1} is also similar to T. *Aus* and T. *Aman* rice that are

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recommended in the current FRG (2018). Further study should be done on N requirement of B. *Aus* in other areas of southwestern region and more similar research is needed in this agro ecological zone (AEZ -13) of Bangladesh.

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CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in Pankhali, Dacope upazila, Khulna situated in the Agro-ecological zone (AEZ) 13 during May 2019 to September 2019 with a view to evaluate the effect of N on yield and investigate the optimum rate of nitrogen for realizing highest grain yield and yield components of a HYV broadcasted *Aus* rice BRRI dhan48. There were 6 different level of nitrogen treatment as N_0 (0 kg N ha^{-1}), N_1 (35 kg N ha^{-1}), N_2 (52 kg N ha^{-1}), N_3 (70 kg N ha^{-1}), N_4 (87 kg N ha^{-1}) and N_5 (104 kg N ha^{-1}) with three replications.

Nitrogen rate had statistically significant effect on plant height, tiller number, dry matter, panicle length, number of grain $panicle^{-1}$, number of filled grain $panicle^{-1}$ and unfilled grain $panicle^{-1}$, grain yield, straw yield and harvest index. At harvest the tallest (83.7 cm) plant was recorded from 70 kg N ha^{-1} and shortest from the control. The highest and lowest number of tillers (6.7) and (2.93) were recorded from 70 kg N ha^{-1} and 0 added N ha^{-1}, respectively. The highest dry matter (8.36 t ha^{-1}) was recorded from 105 Kg N ha^{-1} and lowest total dry matter (4.76 t ha^{-1}) was obtained at control at harvest. The highest panicle length (19.3 cm) was obtained at 70 kg N ha^{-1} whereas the control produced the lowest panicle length (16.20 cm).The highest and lowest number of grains $panicle^{-1}$(85.5) and (53.7) were recorded from 70 kg N ha^{-1} and 0 added N ha^{-1}, respectively. The highest number of filled grains $panicle^{-1}$ (71.06) was counted at 70 Kg N ha^{-1} whereas the control produced the lowest number of filled grains $panicle^{-1}$ (37.4).Among the treatments, 104 kg N ha^{-1}produced the highest number of unfilled grains $panicle^{-1}$ (18.73) whereas the control treatment showed the lowest value (16.2). Though thousand seed weight showed a non significant effect to N application, however, the highest weight of 1000 seed weight (22.8) was found in 70 Kg N ha^{-1} treatment. The highest grain yield (3.9 t ha^{-1}) was

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obtained from 70 kg N ha^{-1} treatment and the lowest grain yield (2.22 t ha^{-1}) was from control. The highest straw yield (4.52 t ha^{-1}) was obtained at 104 kg N ha^{-1} whereas the lowest straw yield (2.37 t ha^{-1}) was obtained from no N. Significantly highest harvest index (47.52%) was obtained at 70 kg N ha^{-1} and the minimum (40.11%) was obtained at 35 kg N ha^{-1}.

It might be concluded that

- Among nitrogen treatments N_3 (70 kg N ha^{-1}) produced the highest plant height (83.7 cm), tiller number (6.7), panicle length(19.3cm), number of grain $panicle^{-1}$(85.53), number of filled grain $panicle^{-1}$ (71.06), grain yield (3.9 t ha^{-1}) and harvest index (47.52)where most of the parameters were statistically similar with N_4 (87 kg N ha^{-1}) and N_5(104 kg N ha^{-1}).Thousand seed weight showed a non significant variation.

This is a single year and single location trial so more research is needed in this agro ecological zone (AEZ -13) of Bangladesh for the conformity of the N rate for T. *Aus* rice.

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REFERENCES

Ahmed, M., Islam, M. and Paul, S. K. 2005. Effect of nitrogen on yield and other plant characters of local T. *Aman* rice, variety Jatai. Research Journal of Agricultural Biological Science. 1(2): 158-161.

Barrett-Lennard, E.G. and Shabala, S.N. 2013. The waterlogging/salinity interaction in higher plants revisited–focusing on the hypoxia-induced disturbance to K^+ homeostasis. Functional Plant Biology 40: 872–882.

BBS (Bangladesh Bureau of Statistics) 2013: Yearbook of Agricultural Statistics of Bangladesh. Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka. pp. 136–140.

BBS (Bangladesh Bureau of Statistics). 2018. Agriculture Statistics of Major Crops. Statistics and Informatics Division (SID), Bangladesh Bureau of Statistics, Government of the people's Republic of Bangladesh. pp. 21-22.

BBS. 2017. The Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning. Dhaka. Bangladesh.

BBS. 2016. The statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning. Dhaka. Bangladesh.

BBS. 2021. The statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning. Dhaka. Bangladesh.

Bell, R.W., Mainuddin, M., Barrett-Lennard, E.G., Sarangi, S.K., Maniruzzaman, M., Brahmachari, K., Sarker, K.K., Burman, D., Gaydon,D.S., Kirby,J.M., Glover, M., Rashid, M.H., Khan,M.S.I., Kabir,M.E., Rahman,M.A. and Hossain, M.B. 2019. Cropping systems intensification in the coastal zone of the Ganges delta: opportunities and risks. Journal of the Indian Society of Coastal Agricultural Research 37(2): 2019.

BRRI (Bangladesh Rice Research Institute). 2006a. Annual Report for 2005-2006. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh. p. 63-67.

BRRI (Bangladesh Rice Research Institute). 2006b. Web site: http://www. knowledge-brri.org. Bangladesh Rice ResearchInstitute, Joydebpur, Gazipur, Bangladesh. pp. 63-67.

BRRI (Bangladesh Rice Research Institute). 2008a. BRRI Annual internal review 2006-2007. Soil Science Division. Bangladesh Rice Research Institute, Gazipur-1701.

@Khulna University

BRRI (Bangladesh Rice Research Institute). 2008b. Annual report for 2007-2008. Bangladesh Rice Research Institute, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute) (2011) Adhunik Dhaner Chash. Bangladesh Rice Research Institute, Joydebpur, Gazipur, 5. (In Bengali)

Chaturvedi, I. 2005. Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (*Oryza sativa)*. Journal of Central European Agriculture. 6(4): 611-618.

Chopra, N. K and Chopra, N. 2004.Seed yield and quality of pusa- 44" rice as influenced by Nfertilizer and row spacing. Indian Journal of Agricultural Science. 74: 144-146.

Chopra, N. K. and Chopra, N. 2000. Effect of row spacing and nitrogen level on growth yield and seed quality of scanted rice (*Oryza sativa*) under transplanted condition. IndianJournalofAgronomy. 45(2): 304-408.

De Datta, S.K. 1981. Principle and Practices of Rice Production. John Wiley and Sons. New York, USA.

Devasenamma,V. Reddy, M. R.andSoundararajan, M. S. 2001. Effect of varying levels of nitrogen on yield and yield components of hybrid rice. Journal Research. ANGRAU. 29(1): 1-3.

Djaman, K., Mel, V. C., Ametonou, F. Y., El-Namaky, R.,Diallo, M. D., and Koudahe, K. 2018. Effect of nitrogen fertilizer dose and application timing on yield and nitrogen use efficiency of irrigated hybrid rice under semi-arid conditions. Journal of Agricultural Science and Food Research, 9(2), 223.https://hdl.handle.net/10568/102040

Dobermann, A. and T. Fairhurst. 2000. Rice: Nutrient Disorders and Nutrient Management. Handbook Series. pp 4-158.

Dwivedi A. P, Dixit, R. S. and Singh, G. R. 2006. Effect of nitrogen, phosphorus and potassium levels on growth, yield and quality of hybrid rice (*Oryza sativa* L.). Department of Agronomy, Narendra Deva University of Agriculture and Technology, Kumarganj,Faizabad, Uttar Pradesh, India. 43(1): 64-66.

Ebaid, R.A. and Ghanem, S.A. 2000. Productivity of Giza 177 rice variety grown after different winter crops and fertilized with different nitrogen levels. Egyptian Journal of Agriculture Research. 87(2): 717-731.

@Khulna University

Ehsanullah, A., Cheema, M.S. and Usman, M. 2001a. Rice Basmati-385 response to single and split application of nitrogen at different growth stages. Pakistan Journal of Biological Sciences38(1-2): 84-86.

El-Batal, M.A., Abd El-Gawad, M.F., Fatina, A. Abdo and El-Set A., El-Aziz, Abd. 2004. Uniconazole application as antilodging for rice plants fertilized with high nitrogen rate. Zagazig Journal of Agricultural Research. 31: 473-490.

Emran, S.A., Krupnikb, T.J., Kumarc, V., Alid, M.Y., and Pittelkowa, C.M. 2019. Agronomic, economic, and environmental performance of nitrogen rates and source in Bangladesh's coastal rice agro ecosystems. Field Crops Research 241(107):567.

Fageria, N.K and Santos, A.B. 2014. Lowland rice genotypes evaluation for nitrogen use. Journal of Plant Nutrition. 37 (9): 1410–1423.

Fageria, N.K. 2009. The Use of Nutrients in Crop Plants. CRC Press, Boca Raton, FL, pp. 20–50.

FAO. Rice Market Monitor; Food and Agriculture Organization (FAO) of the United Nations: Rome, Italy, 2018.

FAO. Rice Market Monitor; Food and Agriculture Organization (FAO) of the United Nations: Rome, Italy, 2021.

Farooq, M, K H M Siddique, H Rehman, T Aziz, D J Lee, and A Wahid. 2011. Rice direct seeding: Experience, Challenges and Opportunities. Soil and Tillage Research. 111:87-98.

Freitas, J.G., Azzini, L.E., Cantarrella, H., Bastos, C.R., Castro-LHSM-de, Gallo, P.B., Felicio, J.C., de-Freitas, J.G. and de-Castro, L.H.S.M. 2001. Response of irrigated rice cultivars to Nitrogen. Scientia Agricola. 58(3): 573-579.

FRG,2018. Fertilizer recommendation guide, Bangladesh Agricultural Research Council (BARC) Farmgate, Dhaka, Bangladesh.

Fu, Q. L., Yu, J. Y. and Chen, Y. X. 2000. Effect of nitrogen applications on dry matter and nitrogen partitioning in rice and nitrogen fertilizer requirements for rice production. J. Zhejiang Univ. Agriculture. Life Science. 26(4): 399-403.

@Khulna University

Ganga, D.M., Tirumala R.S., Sumatin, V., Pratima, T. and John, K. 2012. Nitrogen management to improve the nutrient uptake, yield and quality parameters of scented rice in aerobic culture. International Journal of Applied Biology and Pharmaceutical Technology.3 (1):340-344.

Geethadevi, T., Andani, G., Krishnappa, M. and Babu, B. T. R. 2000. Effect of nitrogen and spacing on growth and yield of hybrid rice. Current Research University of Agricultural Science. Bangalore. 29(5 and 6): 73-75.

Haider, I.K. 2018. Appraisal of biofertilizers in rice: To supplement inorganic chemical fertilizer. Rice Science. 25: 357–362.

Hassan, M.S., Khair, A., Haque, M.M., Azad, A.K and Hamid, A. 2009. Genotypic variation in traditional rice varieties for chlorophyll content, SPAD value and nitrogen use efficiency. Bangladesh Journal of Agricultural Research. 34 (3): 505–515.

Idris, M. and Matin, M. A. 1990. Response of four exotic strains of *aman* rice to urea. Bangladesh Journal of Agrcultural Science.17 (2): 271 -275.

Ingale, B.V., Jadhav, S. N.; Waghmode, B. D. and Kadam, S. R. 2005. Effect of age of seedling, number of seedling hill^{-1} and level of nitrogen on performance of rice hybrid, Sahyadri. Journal of Maharashtra Agriculture University.30 (2): 172-174.

IRRI, 1985. Wetland soil characterization classification and utilization. International Rice Research Institute, Los Banos, Philipines.

Islam M. S., Howlader M. I. A., Rafiquzzaman S., Bashar H. M. K. and Al-Mamun M. H. 2008. Yield Response of Chili and T. *Aman* Rice to NPK Fertilizers in Ganges Tidal Floodplain. Journal of Soil Nature. 2(1): 07-13.

Kabir, M.E., Sarker, B.C., Ghosh, A.K., Mainuddin, M. and Bell, R.W. 2019. Effect of sowing dates for wheat grown in excess water and salt affected soils in southwestern coastal Bangladesh. Journal of the Indian Society of Coastal Agricultural Research 17(2):51-59.

Karmakar, B., Mamun, M .A. A., Rahman, M .S ., Islam, M. A., Islam, M. R., Muku, M. H. R., Zahan,A., Barua,R., Biswash, M. R., Parveen,S., Akter,S., Shaikh,N.Y. and Ahmed,B. Adaptation of promising rice genotypes for broadcast *aus*season. Bangladesh Rice Journal. 23 (2): 35-48, 2019.

@Khulna University

Khatun, A, Hasina S, Islam J A.H.M, Bhuiya U and Saleque A. 2015. Seed yield and quality of lowland rice (*oryza sativa* l.) as influenced by nitrogen from organic and chemical sources. The Agriculturists 13(1): 109-118.

Lang, N., Xu, S. H., Liang, R. J.and Chen, G. S. 2003. Effect of different fertilizer application rates on no-tillage and seedling-throwing rice. Hybrid-Rice. 18(2): 52.

Lawal, M.I. and Lawal, A.B. 2002. Influence of nitrogen rate and placement method on growth and yield of rice (*Oryza sativa*L.) at Kadawa, Nigeria. Crop Research. Hisar. 23(3): 403-411.

Liu Y, Ding YF, Wang QS, Meng DX, Wang SH. 2011. Effects of nitrogen and 6 benzylaminopurine on rice tiller bud growth and changes in endogenous hormones and nitrogen. Crop Science 51:786–792.

Liu, X., Wang, H., Zhou, J., Hu, F., Zhu, D., Chen, Z. & Liu, Y. 2016. Effect of N fertilization pattern on rice yield, N use efficiency and fertilizer-n fate in the yangtze river basin, China. PLoS ONE 11(11): e0166002. doi:10.1371/journal.pone.0166002

MacDonald, G.K., Bennett, E.M., Potter P.A. and Ramankutty N. 2011. Agronomic nitrogen imbalances across the world's croplands. Proceedings of the National Academy of Sciences of the USA. 108:3086–3091

M.Mahmuduzzaman, Z.U. Ahmed, A. K. M.Nuruzzaman, and F. R. S. Ahmed, "Causes of Salinity Intrusion in Coastal Belt of Bangladesh,"International Journal of Plant Research, vol. 4, no. 4A, pp. 8–13, 2014.

Maiti, S., Naleshwar, N. and Pal, S. 2003. Response of high yielding and hybrid rice to varied levels of nitrogen nutrition.Journal of Ecology and Environment. 21(2): 296-300.

Meena, S. L., Sundera, S., and Shivay, Y. S. 2003. Response to hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay-loam soils. Indian Journal ofAgriculture Science.73 (1): 8-11.

Meena, S. L., Surendra, S. and Shivay, Y. S. 2002. Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application. Indian Journal of Agronomy.47 (2): 207-211.

@Khulna University

Munnujan, K., Hamid, A., Hashem, A., Hirota, O. and Khanam, M. 2001. Effects of nitrogen fertilizer levels and planting density on growth and yield of long grain rice. Bangladesh Agricultural Science.9 (2): 19-20.

Munnujan, K., Haniid, A.,Hashem, A., Hirota. 0. and Khanam. M. 2001. Effects of nitrogen fertilizer lcvels and planting density on growth and yield of long grain rice. Bulletin, Institute of Tropical Agriculture. Kyushu University. 24:110.

Neelam, K. C. and Nisha. C. 2000. Effect of row spacing and N level on growth,yield and seed quality of scented (0.5.) under transplanted conditions. Indian Agricultural Science. 45 (2): 304-308.

Rahman, M. S., Miah, A. J. and Mansur, M. A. 1985. Agronomic performance of rice mutants with varying N fertilizer doses and plant spacing. Bangladesh Journal of Nuclear Agriculture. 1(1): 54-64.

Saha, P. K., Islam, S. M. M., Akter, M., andZaman, S. K. 2012. Nitrogen response behavior of developed promising lines of T. *Aman* rice. Bangladesh Journal of Agricultural Research, 37(2), 207–213. https://doi.org/10.3329/bjar.v37i2.11222

S. A. Haque, "Salinity problems and crop production in coastalregions of Bangladesh," Pakistan Journal of Botany, vol. 38, no.5, pp. 1359–1365, 2006.

Salem, A.K.M. 2006. Effect of nitrogen levels, plant spacing and time of farmyard manure application on the productivity of rice. Journal of Applied Scientific Research.2 (11): 980-987.

Sarkar, M. I. U., Islam, M. N., Jahan, A., Islam, A., and Biswas, J. C. 2016. Rice straw as a source of potassium for wetland rice cultivation. Geology, Ecology and Landscapes, 1(3), 184–189. https://doi.org/10.1080/24749508.2017.1361145

Sarkar, S., Pat, S., Mandla, N.N. and Maiti, S. 2001. Response of rice cultivars to different levels of nitrogen. EnvironmentalEcology.19 (1): 118-120.

Sathiya, K. and Ramesh, T. 2009. Effect of split application of nitrogen on growth and yield aerobic rice. Asian Journal of Experimental Sciences. 23(1): 303-306.

Sahrawat, K. L., Diatta, S. and Singh, B. N. 1999. Nitrogen responsiveness of lowland ricevarieties under irrigated condition in west Africa. International Rice Research Institute. 24(2):30.

@Khulna University

Shelley, I J, M T Nosaka, M K Nakata, M S Haque and Y Inukai. 2016. Rice cultivation in Bangladesh: present scenario, problems, and prospects.Journal of International Cooperation for Agricultural Development. 14: 20-29.

S. Huq and G. Rabbani, 2011, Adaptation Technologies in Agriculture; The Economics of rice farming technology in climate vulnerable areas of Bangladesh.

Singh, B. K., and Modgal, S.C. 2005. Pattern of dry mattern accumulation and nitrogen concentration and uptake as influenced by levels and methods of nitrogen application in rainfed upland rice. Journal of PlantScience.52 (1): 9-17.

Sikdar, M S I, M M Rahman, M S Islam, M S Yeasmin and M M Akhter. 2018. Effect ofnitrogen level on aromatic rice varieties and soil fertility status. International Journal ofSustain Crop Production. 3: 49-54.

Singh, S.and Shivay, Y. S. 2003. Coating of prilled urea with eco-friendly neem (Azadirachtaindica A. Juss.) formulations for efficient nitrogen use in hybrid rice. ActaAgronomicaHungarica. 51(1): 53-59.

Singh. M. K., Thakur. R., Verma. U. N., Upasani. R. It. and Pal. S. K. 2000. Effect of planting time and nitrogen on production potential of Basmati rice (*Oryza sativa*) cultivars in l3ihar Plateau. Indian Journal of Agronomy. 45 (2): 300- 303.

Soil Resource Development Institute (SRDI), 2010. Saline Soils of Bangladesh. Ministry of Agriculture, Bangladesh: 1-60.

Subhendu. M., Swamy, S.N. and Mandal, S. 2003. Effect of time of nitrogen application on yield and yield attributes of rice (*Oryza sativa*L.) cultivars.Journal of Ecology and Environment. 21(2): 411-413.

Thakur, R. B. 1993. Perfomiance of summer rice (*Oryza sativa*) to varying levels of nitrogen. Indian Journal of Agronomy. 38(2): 187-190.

UNB. United News of Bangladesh. Govt launches incentive to boost *Aus* production. The Financial Express. http://www. Thefinancialexpress-bd.com/2016/03/27/23283 (2016). Accessed 02 Oct 2017.

@Khulna University

Upendra, R., Dayanand, P. and Choudhary, S. K. 2004. Evaluation of newly developed hybrid rice under different levels of nitrogen and potassium on calcitharants of North Bihar. Journal of Applied Biology.14 (1): 42-43

Verma, A. K., Pandey, N. and Tripathi, R. S. 2004.Leaf growth, chlorophyll, nitrogen content and grain yield of hybrid rice as influenced by planting times and N levels. Annual Agricultural Research .25(3): 456-458.

Wang, R. L., Hua, C. and Wei, J. C. 2002. Effect of nitrogen levels on photosynthetic characteristics of rice variety (combination) Shanyou 64 and Kinmaze. Chinese Journal of Rice Science.16 (4): 331-334.

Xia, W., Wang, W. and Zhang, Q. 2007. Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Proviance. Journal of Zhejiang University of Science. 8(7): 486-492.

Yoshida, H., Horie, T., and Shiraiwa, T. 2006. A model explaining genotypic and environmental variation of rice spikelet number per unit area measured by cross-locational experiments in Asia. Field Crop Research

Yu, Y. Mainuddin, M., Maniruzzaman, M., Mandal, U. K. and Sarangi, S. K. 2019. Characteristics of rainfall and temperature in coastal zones of Bangladesh and west Bengal, India.Journal of the Indian Society of Coastal Agricultural Research 37(2) (in press).

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APPENDICES

Appendix 1. Fertilizer doses

Fertilizer name	Rate (kg ha^{-1})	Basal application	Top dressing		
			1st installment	2nd installment	3rd installment
TSP	52.5	100%	-	-	-
MoP	75	100%	-	-	-
Gypsum	37.5	100%	-	-	-
$ZnSO_4$	5.25	100%	-	-	-

(Source: BRRI, 2008)

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Appendix 3. Physical and chemical properties of the soil (experimental plot soil)

Depth (cm)	Analyzed result and fertility status								
	p^H	Salinity (EC) dS/m	OM	N	P	K	S	Zinc	Boron
			(%)		Micro g/ g soil	Meq./100g soil	Micro g/g soil		
0 - 15	7.3	8.4	2.10	0.122	34.56	0.41	102.91	1.84	1.41
	Neutral	Medium	Medium	Low	High	High	Highest	High	Highest
15 - 30	7.3	6.3	2.17	0.126	28.12	0.28	111.92	1.17	0.90
	Neutral	Low	Medium	Low	Optimum	Optimum	Highest	Medium	Highest

OM= Organic matter, N= Nitrogen, P= Phosphorus, K= Potassium, S= Sulphur

(Source: Soil Resources and Development Institute (SRDI), Khulna.)

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Appendix 4. Layout of the experimental field

R-1	R-2	R-3
N_2	N_2	N_5
N_4	N_0	N_0
N_5	N_5	N_1
N_1	N_1	N_2
N_3	N_4	N_3
N_0	N_3	N_4

Plot size = 5m x 2 m   Replication to replication distance: 1 m   Plot to plot distance: 0,5 m

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