

**EFFECT OF NITROGEN RATES AND PLANTING METHODS ON GROWTH
AND YIELD OF LATE SEASON AUS RICE IN THE SOUTHWESTERN COASTAL
REGION OF BANGLADESH**

A Thesis

By

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Student ID: MS 230809



**A Thesis (Course No. 011108 IER 6160) Submitted to the Agrotechnology
Discipline in Partial Fulfillment of the Requirements for the Degree of
Master of Science**



**AGROTECHNOLOGY DISCIPLINE
LIFE SCIENCE SCHOOL
KHULNA UNIVERSITY
KHULNA-9208**

JANUARY, 2025

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**AGROTECHNOLOGY DISCIPLINE
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JANUARY, 2025

DEDICATED
TO
MY BELOVED PARENTS

Effect of Nitrogen Rates and Planting Methods on Growth and Yield of Late Season Aus Rice in the Southwestern Coastal Region of Bangladesh

ABSTRACT

The current study was conducted during the late aus season (June-September) of 2023 at the Prof. Dr. Purnendu Gain Field Laboratory of the Agrotechnology Discipline of Khulna University, Khulna. The primary aim of this research was to assess the impact of varying nitrogen rates (0, 52, 69, 86, and 104 kg nitrogen ha⁻¹) on the growth and yield of the BRRI dhan48, utilizing four different sowing methods: broadcasting, line sowing, hill sowing, and transplanting. The experimental design employed a factorial randomized complete block design with three replications. The following data were collected: plant height (cm), tiller number m⁻², panicle m⁻², panicle length, filled grains panicle⁻¹, unfilled grains panicle⁻¹, 1000-grain weight, grain yield, straw yield, biological yield and harvest index. A combined analysis was performed to evaluate the interaction between planting methods and nitrogen rates. The findings indicate that the transplanting method with 86 kg N ha⁻¹ (125%) nitrogen significantly enhanced plant height (82.63 cm), panicle m⁻² (847.33), number of filled grains per panicle (111.00), 1000-grain weight (31.39 g), grain yield (4.06 t ha⁻¹), and harvest index (44.99%) when compared to the broadcasting, line, and hill sowing methods. Increasing nitrogen rates up to 104 kg N ha⁻¹ (150%) led to a significant rise in plant height, chlorophyll content index, and straw yield. The transplanting method resulted in a notable rise in plant height, number of tillers, chlorophyll content index, panicle length, 1000-grain weight, grain yield, and harvest index over hill sowing, line sowing and broadcasting excluding straw yield. It can be concluded that application of 125% N (86 kg ha⁻¹) with transplanting methods is suitable for the cultivation of aus rice (BRRI dhan48) during late season in southwestern coastal Bangladesh.

Keywords: *Rice, Planting methods, Nitrogen, Coastal are and Aus rice.*

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The Author

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is an essential source of nourishment for over fifty percent of the global population, especially in areas such as Bangladesh, where it is a key component of the diet (Islam et al., 2018). The climatic condition of Bangladesh is suitable for cultivating rice throughout the year. However, compared to other rice-growing nations, the average national yield of rice in Bangladesh is substantially lower (2.94 t ha^{-1}) against the global average of 3.18 t ha^{-1} (IRRI, 2019). Rice is cultivated across three distinct seasons: Aus (April to June), Aman (wet season, July to November), and Boro (dry season irrigated, December to June) in Bangladesh (Shelly et al., 2016). Aus rice represents approximately 8.97% of the overall cropped area, with modern varieties accounting for 6.65% and local varieties for 2.32%. In terms of total production, 6.88% is contributed by Aus rice, wherein modern varieties provide 5.91% and local varieties contribute 0.98%. Currently, the total area dedicated to Aus rice is 1.3 million hectares, yielding a production of 3.28 million metric tons. (BBS, 2021). In the coastal areas of southwestern Bangladesh, where climatic conditions and soil properties often pose challenges to agricultural productivity, the cultivation of rice, especially late-season Aus rice (BRRI dhan48), holds paramount importance for food security and economic sustainability (Islam et al., 2016). However, maximizing rice yield in these regions necessitates a comprehensive understanding of various agronomic factors, including planting methods and nitrogen fertilization rates.

The choice of planting methods significantly influences rice growth, development, and ultimately yield. Broadcasting, line sowing, hill sowing, and transplanting represent common planting methods practiced in rice cultivation (Das et al., 2015). Each method offers unique advantages and challenges concerning seed rate, land preparation, water management, and labor requirements. Previous studies have elucidated the impact of these planting methods on rice yield and resource use efficiency (Islam et al., 2016; Das et al., 2015). However, extensive studies concentrating on their effectiveness, particularly in late-season Aus rice farming in the coastal regions of southwestern Bangladesh, are still scarce.

Plant nutrients play a pivotal role in facilitating the growth and development of plants. Among these nutrients, nitrogen is classified as macronutrients due to its substantial requirement by plants compared to other nutrients. Moreover, nitrogen (N) stands as a primary macronutrient essential for rice growth and productivity. Throughout the growth cycle of rice, from

emergence to maturation, several critical stages such as tillering, panicle initiation, booting, heading, and maturation emerge. During these stages, the rice crop exhibits heightened sensitivity, making it imperative to shield the plants from nutritional stress (Islam et al., 2016). Ensuring adequate nutrient supply, particularly during these sensitive stages, is crucial for promoting optimal growth, development, and ultimately, maximizing yield potential. Adequate nitrogen application significantly influences various physiological processes, including photosynthesis, nutrient uptake, spikelet formation, biomass accumulation, root development and yield formation in rice plants (Jahan et al., 2020; Fageria and Santos, 2014). Nitrogen application, during the panicle initiation stage is preferable (Miah et al., 2016). However, the optimal nitrogen rate depends on several factors, including soil type, cultivar, environmental conditions, and management practices. Suboptimal nitrogen application may lead to yield losses, resource inefficiency, and environmental degradation, while excessive nitrogen usage can exacerbate environmental pollution and diminish economic returns (Dobermann and Cassman, 2002). Farmers may find it challenging to manage nitrogen fertilization in rice fields due to the denitrification of ammonium nitrate in flooded soils, with urea being the primary nitrogen source for rice.

Consequently, clarifying the combined impacts of various planting methods and nitrogen applications on late-season Aus rice farming in the coastal regions of southwestern Bangladesh is crucial for improving agricultural sustainability, productivity, and the capacity to withstand environmental challenges. This study aims to address this critical knowledge gap by systematically evaluating the performance of broadcasting, line sowing, hill sowing, and transplanting methods across varying nitrogen rates (75%, 100%, 125%, and 150% of recommended dosage) on the growth and yield of BRRI dhan48 rice cultivar. Through rigorous experimentation and analysis, this research endeavors to provide valuable insights and evidence-based recommendations to optimize rice production practices and support food security initiatives in the region.

The research will be carried out with the objectives listed below:

- To investigate the effect of different planting methods and nitrogen rate on growth and productivity of late season Aus rice.
- To found out the suitable planting method and optimum nitrogen rate for late season Aus rice in the southwestern coastal soil of Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

2.1 Worldwide rice production

Rice (*Oryza sativa* L.) stands as one of the most vital cereal crops globally, serving as a staple food source for over half of the world's population (Mohidem et al., 2022). According to recent data from the Food and Agriculture Organization (FAO), global rice production has steadily increased over the years, reaching approximately 500 million metric tons annually (FAO, 2023). This production is predominantly concentrated in Asia, which contributes around 90% of the global rice output (FAO, 2023). The significance of rice in global food security and its role in various socio-economic contexts make it a subject of extensive research and development efforts worldwide.

In recent years, advancements in rice cultivation practices, including breeding techniques, agronomic management, and mechanization, have contributed to enhancing productivity and sustainability in rice production systems. Moreover, the adoption of precision agriculture technologies and digital farming approaches has further revolutionized rice cultivation, enabling farmers to optimize resource use and mitigate environmental impacts (Hashim et al., 2024).

Rice is an important source of nutrition for people in the Asia-Pacific area, sections of Latin America and the Caribbean, and, increasingly, Africa (Sen et al., 2020)). In underdeveloped countries, over 200 million households depend on rice production as their main source of income and employment (Muthayya et al., 2014).

2.2 Rice production in Bangladesh

Rice is the major food crop of Bangladesh, playing an important role in the country's economy, food security, and cultural heritage. With a population exceeding 160 million and predominantly agrarian society, rice cultivation occupies a central position in Bangladesh's agricultural landscape (BBS, 2021).

The geographical diversity of Bangladesh, coupled with its monsoonal climate, facilitates the cultivation of rice throughout the year. The country's three main rice-growing seasons include Aus (March-June), Aman (July-November), and Boro (December-April) (Sarker et al., 2012). Among these, the Boro season contributes the most significant share to the total rice production, followed by Aman and Aus seasons.

In recent years, Bangladesh has made significant strides in rice production, achieving remarkable increases in both yield and total production. According to data from the Bangladesh Bureau of Statistics (BBS), rice production in Bangladesh surpassed 35 million metric tons in the fiscal year 2019-2020, marking a notable achievement in the country's efforts towards food self-sufficiency (BBS, 2021).

Currently, the country produces around 33.0 million tons of food, enough to feed 160 million people (Barmon and Chaudhury, 2012). Bangladesh's rice output might be 35.5 million tons this year, according to the US Department of Agriculture's November grain prediction for FY 2021-22, despite a low harvest in the *Aus* season. Rice output was over 36.3 million tons in FY21, according to preliminary estimates from the Bangladesh Bureau of Statistics (BBS). Based on the latest USDA forecast, rice production in FY22 is expected to decrease by 0.8 million tons. According to the latest USDA study, rice output in Bangladesh for marketing year (MY) 2021-22 might be 35.5 million tons on 11.42 million hectares, which is 2.2% and 2.1% lower than the USDA's official prediction (Wardad, 2021).

The achievements in rice production in Bangladesh can be linked to several elements, such as the implementation of high-yield rice varieties, enhanced farming techniques, growth of irrigation facilities, and governmental backing through policies and incentives. Additionally, the introduction of modern technologies such as hybrid rice cultivation, integrated pest management, and precision agriculture has further contributed to enhancing rice productivity and resilience to climate variability. Despite these advancements, challenges such as land scarcity, soil degradation, water management issues, and the adverse impacts of climate change pose significant threats to sustainable rice production in Bangladesh (Shelly et al., 2016).

2.3 Rice production in southwestern Bangladesh

Rice cultivation in the southwestern region of Bangladesh, characterized by its unique coastal landscape, is vital for sustaining livelihoods and ensuring food security in the area. The coastal districts of Khulna, Satkhira, Bagerhat, and Patuakhali are among the major contributors to rice production in this region (Hossain et al., 2019).

The agro-ecological conditions of southwestern Bangladesh present both opportunities and challenges for rice cultivation. The region's proximity to the Bay of Bengal exposes it to saline intrusion, waterlogging, and cyclonic disturbances, which significantly influence rice productivity and cropping patterns (Hossain et al., 2019). However, the presence of tidal rivers

and canals provides irrigation water during the dry season, enabling multiple cropping cycles and diversification of agricultural activities.

Kharif is the main growing season in the area. In low saline areas, rice production during kharif season averages 4,232 kg ha⁻¹, while in moderate and high saline areas, it is 3,760 kg ha⁻¹ and 2,663 kg ha⁻¹, respectively (Ahmed and Haider, 2014). The intrusion of salinity has a detrimental impact on both farm profitability and farm performance.

In recent years, the adoption of improved rice varieties, such as BRRI dhan48, created by the Bangladesh Rice Research Institute (BRRI), has played a crucial role in enhancing rice productivity and resilience to environmental stresses in southwestern Bangladesh (Haque et al., 2019). BRRI dhan48, known for its tolerance to salinity and submergence, has gained popularity among farmers in coastal areas due to its high yield potential and adaptability to adverse growing conditions.

Despite these advancements, rice production in southwestern Bangladesh faces several challenges, including soil salinity, water scarcity, pest and disease outbreaks, and inadequate infrastructure for post-harvest management (Haque et al., 2019). Additionally, climate change-induced phenomena such as sea-level rise and increased frequency of extreme weather events pose long-term threats to rice cultivation sustainability in the region.

2.4 The effect of planting methods on growth and yield of rice

Sharma et al. (2023) stated that the transplanting method of rice planting exhibited superior performance compared to the broadcasting method concerning yield attributing traits and overall yield. Notably, the broadcasting method displayed a notable decrease in tiller number, biological yield, and grain yield compared to line sowing. However, it's worth mentioning that the late line sown rice demonstrated better performance than the early line sown rice.

Das et al. (2015) stated that line sowing was more effective than broadcasting technique for Leaf Area Index (LAI) (3.89), total count of tillers per hill is 4.31, the total number of spikelets per panicle is 102.33, the panicle length measures 21.60 cm, the dry matter per plant weighs 31.17 g, the weight of 1000 grains is 25.33 g, the grain yield amounts to 3.29 t ha⁻¹, the straw yield is 6.12 t ha⁻¹, and the biological yield totals 9.41 t ha⁻¹. Among all varieties, BRRI dhan48 showed the highest grains per panicle⁻¹ (106), LAI (5.568), and 1000-grain weight (29.73 g) and highest harvest index (44.54%),

Ahmed et al. (2007) observed the cultivation method significantly impacted the characteristics under analysis, with the exception of panicle length, 1000-grain weight, and straw yield. Transplanting yielded the most grain (8.73 t ha^{-1}) and straw (9.21 t ha^{-1}), whereas SRI (System of Rice Intensification) yielded the least grain and straw. SRI had the highest harvest index (52.47%), while sprouted seeds disseminated had the lowest at 46.22%.

Abou-Khadrah et al. (2014) demonstrated that the transplanting strategy on April 15th resulted in a much larger number of tillers m^{-2} , spikelets weight (g), panicle density (%), panicle length (cm), flag leaf area (cm^2), flag leaf angle ($^\circ$), and number of grains/panicle. During the 2012 and 2013 seasons, GZ 9057 recorded the greatest values for grain production (4.31% and 4.65 t/fed) under the transplanting method with an early sowing date. The transplanting strategy used to seed line GZ7112 on April 15th resulted in significantly increased plant height (cm) and total duration over the course of the two seasons. Additionally, during the 2013 and 2013 season, Sakha 105, which was sown on April 15th utilizing the transplanting method, generated much greater 1000 grain weight.

Rana et al. (2014) stated that rice crops cultivated through direct seeding of both dry and sprouted seeds reached maturity seven days earlier than those established *via* transplanting. Among the varieties tested, BRRI dhan39 produced the highest yield, when grown by directly sowing sprouting seeds. Additionally, this method yielded the greatest net return of 23,362.00 BDT ha^{-1} and a cost-benefit ratio of 1:1.49.

Ali et al. (2013) revealed that the grain yield and cost-benefit ratio of various planting methods ranked as follows: direct seed dibbling, direct seed drilling, and pre-germinated seed broadcasting, line transplantation and conventional transplantation. The line transplantation technique achieved the highest measurements, including plant height at 111.67 cm, productive tillers at 337.67 m^{-2} , panicle count at 330.67 m^{-2} , root length at 17.12 cm, seed index at 27.27 g, straw yield at 14.40 t ha^{-1} , and a cost-benefit ratio of 1:1.82.

Potkile et al. (2018) demonstrated that the highest grain yield, measuring 27.96 q ha^{-1} , and straw yield, amounting to 42.93 q ha^{-1} , were achieved through the PKV SRI transplanting method. This method demonstrated a significant advantage compared to drilling methods.

2.5 The effect of nitrogen rates on growth and yield of rice

Akhter et al. (2023) discovered that regardless of variety, raising the N rate raises the content of grain and straw. However, in all kinds, increased N concentration and absorption were noted

in the N rate of N60-N100 kg ha⁻¹. Out of all the types, BRRI dhan82 had the highest grain nitrogen absorption (61.23 kg ha⁻¹). Additionally, BRRI dhan48 showed higher total N absorption at 80 kg N ha⁻¹. HI ranged from 55 to 72% depending on the N level, indicating that between 45% and 32% of the absorbed N remained in the dry matter within types and that the remaining N was translocated to the grains. The optimal nitrogen dose for achieving maximum yield was evaluated through regression analysis, revealing that the nitrogen rates for BR26, BRRI dhan48, and BRRI dhan82 were 95, 55, and 97 kg, respectively.

Islam et al. (2012) reported that nitrogen application greatly boosted rice grain production compared to the control. Urea @ 80kg N/ha generated the maximum yields of grain and straw (4.63 and 7.80 t ha⁻¹). Application of different sources of nitrogen raised straw yield from 19 to 73% and grain yield from 14 to 45%. When it came to rice yield, urea @ 80 kg N/ha seemed to be the most effective source of nitrogen, followed by ammonium sulfate and calcium nitrate.

Uddin et al. (2013) revealed that application of nitrogen at 80 kg ha⁻¹ produced the highest number of total spikelets and maximum number of grains panicle⁻¹ resulted in the highest grain yield. The impact of nitrogen and potassium interaction had a notable influence on all parameters except 1000-grain weight. The top grain production in NERICA 1 rice was achieved by applying 80 kg N ha⁻¹ and 40 kg K₂O ha⁻¹ simultaneously. A direct correlation was seen between the number of productive tillers and grains per panicle in NERICA 1 rice, positively impacting the grain yield, following a linear trend. According to the findings, it is suggested to use 80 kg N ha⁻¹ and 40 kg K₂O ha⁻¹ for higher NERICA 1 rice grain yield in the Aus season.

Paul et al. (2017) found that the applying 105 kg N ha⁻¹ resulted in the maximum plant height (77.54 cm) at harvest, while control plots had the least plant height (73.28 cm). Fertilization with 70 kg N ha⁻¹ produced the greatest number of tillers per hill was observed to be 11.96, while the count of effective tillers per hill stood at 10.39. The average number of grains per panicle was 151.10, leading to a grain yield of 2.95 t ha⁻¹ and a straw yield of 3.58 t ha⁻¹, resulting in a harvest index of 45.12%. In contrast, the control treatment displayed the lowest figures, with effective tillers per hill at 3.68, grains per panicle at 133.83, grain yield at 0.91 t ha⁻¹, straw yield at 1.52 t ha⁻¹, and a harvest index of 36.65%.

Faruk et al. (2021) found that the tallest plant in the nitrogen management study reached a height of 161.60 cm, while the highest leaf area index recorded was 2.97, there were 115

effective tillers in the highest hill, the longest panicle measured 24.30 cm, and the highest quantity of filled grains recorded 94.73. The weight of 1000 grains yielded 29.97 g. The results showed that the USG yielded 2.48 t ha⁻¹ at 52 kg N ha⁻¹, and the control group had the shortest plant height with the minimum leaf area index (1.78), least number of effective tillers hill⁻¹ (8.43), the shortest panicle length (18.84 cm) along with the lowest number of filled grains (53.18), a 1000-grain weight of (24.33 g), and the greatest grain yield (1.40 t ha⁻¹).

Akhter (2020) found that the maximum panicle density recorded was 269.67 m⁻², and the highest number of grains per panicle was 106.00, both achieved in the BRRI dhan48 variety under N₈₀ treatment. Additionally, BRRI dhan48 produced the highest grain output of 5.52 t ha⁻¹, followed by BRRI dhan82 which yielded 4.52 t ha⁻¹ and BR26 with 4.51 t ha⁻¹, all from N₈₀ treated plots.

2.6 Effect of planting methods with N rates on growth and yield of Aus rice

The choice of planting method and nitrogen rates significantly influences the growth and yield of late-season Aus rice, especially in the coastal regions of southwestern Bangladesh. Several studies have investigated the interaction between planting methods and nitrogen application rates to identify the optimal combination that maximizes rice productivity while minimizing input costs and environmental impacts.

Line sowing has been identified as a promising planting method for late-season Aus rice, as it consistently outperforms broadcasting, hill sowing, and transplanting regarding features that contribute to yield and grain yield (Das et al., 2015). Line sowing facilitates better plant spacing, uniform nutrient distribution, and enhanced resource utilization efficiency, contributing to improved crop growth and yield.

Furthermore, the application of nitrogen fertilizer at varying rates has a profound impact on the growth and development of late-season Aus rice. Research findings suggest that nitrogen rates of 100% (equivalent to 150 kg/ha) tend to optimize rice yield while maintaining economic efficiency and environmental sustainability (Shrestha et al., 2022). Excessive nitrogen application beyond the optimum level can lead to lodging, nutrient imbalances, and environmental pollution, whereas insufficient nitrogen may limit yield potential and profitability.

Afroge et al. (2022) revealed that the maximum plant height (96.22 cm), total tillers per hill (24.79), number of unproductive grains per panicle (22.09), weight of a thousand grains (25.43

g), and straw yield (7.26 t ha^{-1}) were achieved with 180 kg of urea per hectare. The lowest grain yield (2.95 t ha^{-1}) was recorded at the minimum urea dose (90 kg ha^{-1}), while the highest grain yield (3.78 t ha^{-1}) was also noted with $180 \text{ kg urea ha}^{-1}$. Notably, this yield was statistically comparable to that obtained with $150 \text{ kg urea ha}^{-1}$. Interestingly, the highest harvest index (37%) was noted with $120 \text{ kg urea ha}^{-1}$. This study demonstrated that using urea beyond its optimal amount can lead to fertilizer wastage, but increasing the urea dose incrementally improves plant vegetative growth, straw production, and grain yield.

The interaction between planting methods and nitrogen rates has been explored to determine their combined effects on rice growth and yield. Studies have revealed that line sowing combined with moderate nitrogen rates (100%) generally results in superior yield performance compared to other planting methods and nitrogen levels (Sorour et al., 2016). This combination enhances crop establishment, nutrient uptake, and biomass accumulation, leading to increased grain yield and overall farm profitability.

CHAPTER III

MATERIALS AND METHODS

The purpose of the experiment was to assess how planting systems and nitrogen (N) rates affects the growth and yield of the high yielding Aus rice variety BRRI dhan48. A synopsis of the location, climate, soil, and crop may be found in this section. Conception and execution of the experiment, as well as cultural practices and statistical analysis of the collected data. The materials and the methodologies utilized in this study are discussed below.

3.1 Details of experimental site

The experiment was conducted at the Prof. Dr. Purnendu Gain Field Laboratory within the Agrotechnology Discipline at Khulna University, located in Khulna. The experimental site was in the Batiaghata Upazila of Khulna district where latitude 22°47'58" N and longitude 89°31'49" E. The research area was situated within the agro-ecological zone of the Gangetic Tidal Flood Plains (AEZ-13). The soil of this area is characterized as grey in color, with a silt clay to loam texture. It is calcareous and belongs to the Bajoa soil series.

3.2 Period of experiment

The experiment took place in late *Aus* season (June- September). Sowing of seeds were done at 08 June, 2023 and harvesting were done at 20 September, 2023.

3.3 Soil sampling, processing, and analysis

Before seedbed preparation, a composite soil sample was taken from four different locations of the experimental site and carefully combined. Plant roots, leaves, and other inert particles were picked up and removed before drying. After oven drying, the soil sample was passed through a 10-mesh sieve and placed in a clean plastic container. The physical and chemical analysis of the soil were analyzed from Soil Resources Development Institute (SRDI), Khulna (Table 1).

3.4 Weather and Climate

The experimental field was a low-lying area with an elevation of 2-3 m above mean sea level and was a part of the Ganges Tidal Floodplain agro-ecological zone. However, the experimental area was located in a sub-tropical monsoon climate, which is distinguished by high temperatures, heavy rainfall, high humidity, and a long day from April to September (the *kharif* season), and low rainfall, low temperatures, low humidity, and a short day in the rabi season. The southwest coastal region of Bangladesh experiences abundant sunshine and

moderately temperate temperatures throughout the *Rabi* season (October to March) (Appendix 1).

Table 1. Physical and chemical properties of the experimental soil

Parameters	Soil Test Value	Status
pH	8.0	Moderate
EC (dS m ⁻¹)	4.9	Low
Organic matter (%)	1.68	Low
Nitrogen (%)	0.097	Low
Phosphorus (µg g ⁻¹)	25.27	High
Potassium (meq 100 g ⁻¹)	0.70	Very High
Sulphur (µg g ⁻¹)	44.53	Very High
Zinc (µg g ⁻¹)	0.85	Low
Boron (µg g ⁻¹)	1.68	Very High

Source: Soil Resources Development Institute (SRDI), Khulna

3.5 Planting material

BRR1 dhan48 is a high yielding variety used as plant material. The seed was acquired from Bangladesh Agricultural Development Corporation (BADC) regional station, Fultola, Khulna.

3.6 Experimental design, layout and treatments

The experiment was set up in a factorial Randomized Complete Block Design with three replications. Each unit plot measured at 4.0 m x 1.5 m. The gaps between the blocks were 100 cm, while the gaps between the plots measured 50 cm.

Treatments

Factors	Symbol	Description
Factor A (N rates)	N ₀	No nitrogen added (control)
	N ₁	75% of recommended dose (52 kg ha ⁻¹)
	N ₂	100% of recommended dose (69 kg ha ⁻¹)
	N ₃	125% of recommended dose (86 kg ha ⁻¹)
	N ₄	150% of recommended dose (104 kg ha ⁻¹)
Factor B (Planting Methods)	P ₁	Broadcasting
	P ₂	Line sowing
	P ₃	Hill sowing
	P ₄	Transplanting

3.7 Field and crop management

3.7.1 Field preparation

A power tiller was used twice to accomplish minimum tillage. After tillage, the field's stubbles were entirely manually cleaned. According to the design, the field was divided into unit plot size ($4\text{m} \times 1.5\text{m} = 6\text{m}^2$).

3.7.2 Fertilizer application

Urea, Triple Superphosphate (TSP) (1.62 kg), Muriate of Potash (MoP) (2.34 kg), and gypsum (1.2 kg) served as the sources of nitrogen, phosphorus, potassium, sulfur, and zinc. All the fertilizers except urea were applied on the day of final land preparation. Urea (5 kg) was applied as top dressed in three equal splits at 10, 30 and 45 days after sowing/transplanting (DAS/DAT).

3.7.3 Seed sowing

The seed were sown on 08 June, 2023 by using broadcasting, line and hill sowing whereas the for transplanting the seeds were sown in the seed bed and transplanting (25 days seedling) was done on 02 July, 2023.

3.7.4 Care after sowing/transplanting

After establishment of seedlings, various intercultural practices, including weeding, urea split application, and irrigation, were implemented. Additionally, plant protection strategies were employed whenever required.

3.7.5 Weeding

Weeding was done manually twice. The first weeding was accomplished 20 days after sowing or transplanting (DAS/DAT), and the second weeding took place at 35 DAS/DAT.

3.7.6 Plant protection

Systemic fungicide Nativo 75 WG was applied at 45 DAS/DAT and 55 DAS/DAT to protect from rice blast.

3.3.7 Harvesting and postharvest operations

When 80-90 % of the grains had turned golden-yellow in color then the crops were harvested. The harvesting was done on 20.09.23. Threshing was done manually after the harvest. The grains were cleaned and dried to 14% moisture content and the straw were oven dried. The grain and straw yields of each treatment were calculated and converted to $t\ ha^{-1}$.

3.8 Data collection, recording and calculation.

Five hills were selected per plot to record the yield attributes of crops. The data on growth parameters (plant height and tiller number m^{-2}) was collected from the randomly selected five plants from each plot at 30, 45, 60, 75 days after sowing (DAS) and at harvest. Others data were collected on effective tiller $hill^{-1}$, panicle length, grain $panicle^{-1}$, filled grain $panicle^{-1}$, grain yield, straw yield, biological yield and harvest index.

3.8.1 Plant height (cm)

The measurement of the plant's height was taken from the ground level to the peak of the tiller at 30, 45, 60, 75 DAS/DAT, and again during the harvest period.

3.8.2 Number of tillers m^{-2}

The tillers number from $1\ m^2$ was documented at 30, 45, 60, 75 DAS/DAT, and during the harvest.

3.8.3 Panicles m^{-2}

Grain bearing panicle was called effective tiller. After harvesting, the total count of effective tillers was recorded.

3.8.4 Panicle length (cm)

From five randomly selected panicles, panicle length was measured separately from each plot.

3.8.5 Number of grains $panicle^{-1}$

Using the grain yield spikelet as a reference, the overall grain count was collected from five randomly chosen plants within a plot, and the mean number of grains per panicle was recorded.

3.8.6 Filled grains $panicle^{-1}$

The quantity of filled grains was taken from five randomly chosen plants in a specific area, and mean quantity of filled grains per panicle was determined.

3.8.7 Unfilled grains panicle⁻¹

Based on the spikelet grain yield, the sum of unfilled grains was measured from five randomly chosen plants in a plot, and the average counts of unfilled grains per panicle was determined.

3.8.8 Weight of 1000 grain (g)

From the total amount of clean grain in each treatment, a thousand grains were randomly selected, measured in grams and documented.

3.8.9 Grain yield (t ha⁻¹)

The harvested grains from each treatment plot were dried in the sun and meticulously measured. The weight of the grain collected from a 1 m² area was transformed into t ha⁻¹.

3.8.10 Straw yield (t ha⁻¹)

The straw yield was determined similarly to the grain yield, then sun-dried, weighed precisely, and transformed into t ha⁻¹.

3.8.11 Harvest index (%)

The harvest index was determined by using the grain and straw yield of rice from each plot and expressed as a percentage. The harvest index is computed using the formula:

$$\text{Harvest index (\%)} = (\text{Grain yield} / \text{Biological yield}) \times 100$$

3.9 Statistical analysis

All collected data were organized and examined through a two-way analysis of variance (ANOVA) using the software program 'Statistix-10'. The comparison of means across treatments was carried out using Tukey's HSD test at a 95% confidence level. A simple linear regression analysis was conducted using MS-Excel to establish a functional relationship between grain yield and straw yield, grain yield and biological yield, as well as grain yield and the harvest index of BRRI dhan48.

CHAPTER IV

RESULTS AND DISCUSSION

The goal of the study was to determine how N rates and planting methods impact the expansion, yield characteristics, and production of Aus rice variety BRRI dhan48 under late planting conditions. The results of the study were obtained by examining the response of late season aus rice (BRRI dhan48) to varying levels of N and planting methods. The results of this study are shown and clarified with the headings and subheadings provided below-

4.1. Plant height (cm)

4.1.1. Effect of N rates

Results of the present study showed that plant height was varied significantly ($p < 0.01$) by nitrogen levels as shown in Fig. 1. The maximum mean plant height (86.71 cm) was derived at 75 DAS from the highest dose of N application (104 kg N ha^{-1}) followed by $86.25 \text{ kg N ha}^{-1}$ (83.12 cm) and the shortest plant (51.38 cm) was recorded from 0 kg N ha^{-1} . The shortest plants found in the control plots due to deficiency of N in the growth stages of crops. This trend can be linked to the elevated nitrogen dosage, which significantly enables the plant to realize its growth potential (Ali et al., 2011). According to Somasundram et al., (2002), applying nitrogen at a rate of 125 kg per hectare led to the greatest plant height. Ghoneim et al., (2018) demonstrated that varying nitrogen concentrations had notable impacts on plant height, rate of 220 kg N ha^{-1} resulted in the tallest plant.

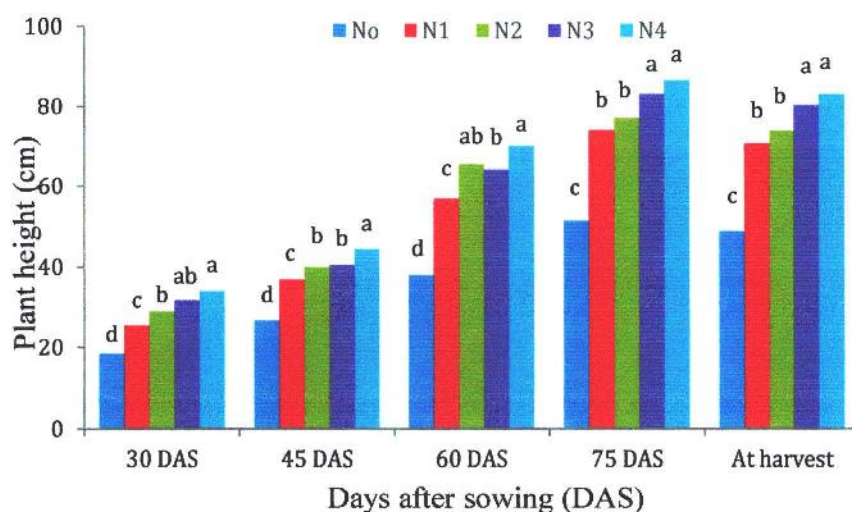


Fig. 1. Plant height of late season aus rice as affected by nitrogen rates.

Here, $N_0 = 0$, $N_1 = 52$, $N_2 = 69$, $N_3 = 86$ and $N_4 = 104 \text{ kg/ha}$ nitrogen. Different letters on the bar indicate the means are statistically different.

4.1.2. Effect of planting methods

The findings of present study indicated that plant height was significantly influenced by sowing methods as shown in Fig. 2. The height of aus rice increased over time gradually and reached the maximum at harvest in all the sowing methods. The maximum average plant height of 76.75 cm was achieved using the transplanting method at 75 DAS, while hill sowing contributed to a height of 76.39 cm. In contrast, the lowest average plant height recorded was 70.17 cm through the broadcasting method. Among the various treatments, transplanting methods typically demonstrated superior growth performance in comparison to broadcasting methods (Sharma et al., 2023). Dendup and Chhogyel (2018) found the same result that the transplanting method led to taller plants than direct seeding with drum seeder and manual broadcasting. The average plant heights were 117 cm for both broadcasting and drum seeding, and 120 cm for random transplanting. According to Akram et al., (2013), the highest plant height (112 cm) was recorded in transplantation followed by conventional recorded in line sowing. The lowest plant height recorded (103 cm), which was achieved through broadcasting.

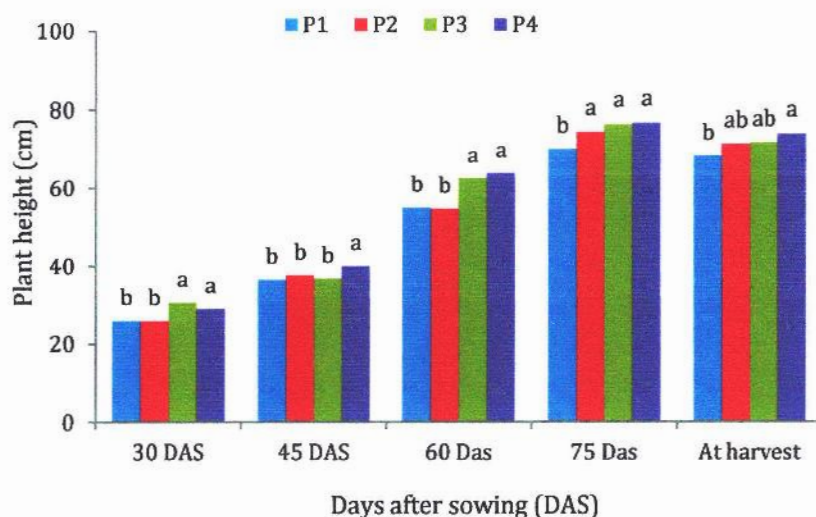


Fig. 2. Plant height of late season aus rice as affected by planting methods.

Here, P1= Broadcasting, P2= Line sowing, P3= Hill sowing and P4= Transplanting. Different letters on the bar indicate the means are statistically different.

4.1.3. Interaction of nitrogen rates and planting methods

The combined impact of different nitrogen rates and planting methods had a notable effect on plant height, as indicated in Table 2. Plant height was observed highest (89.17 cm) from the combination of transplanting and nitrogen at 104 kg ha⁻¹ followed by hill sowing (83.93 cm). Combination of broadcasting with no nitrogen resulted in the shortest plant height (42.83 cm). Combination of line sowing with no nitrogen resulted in the second lowest plant height (46.50 cm).

Table 2. Interaction effect of N rates and planting methods on plant height of late season aus rice grown in the coastal soil of southwestern Bangladesh

Interaction of N rates and planting methods	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N ₀ P ₁	16.22i	24.38i	36.43ij	42.83gh	44.30h
N ₀ P ₂	17.03hi	26.86hi	33.23j	46.50h	40.83h
N ₀ P ₃	18.71g-i	26.87hi	38.83ij	63.07f	58.73fg
N ₀ P ₄	21.81f-h	28.50h	43.37hi	53.13g	51.00gh
N ₁ P ₁	22.81e-g	39.24de	48.46gh	65.63f	64.20ef
N ₁ P ₂	26.15d-f	35.75fg	55.23fg	80.43bc	66.73d-f
N ₁ P ₃	30.79b-d	33.57g	60.36ef	72.87de	67.80c-f
N ₁ P ₄	21.68f-h	38.73d-f	63.22de	77.13cd	73.33a-e
N ₂ P ₁	28.15d	39.59de	61.55d-f	68.40ef	66.73d-f
N ₂ P ₂	29.76cd	42.03b-d	68.137b-d	81.23bc	77.17a-e
N ₂ P ₃	31.21b-d	37.54ef	67.68b-e	76.80cd	72.63b-e
N ₂ P ₄	36.77d-f	40.76c-e	64.42c-e	81.67bc	78.70a-d
N ₃ P ₁	28.33d	37.55ef	64.70c-e	83.23a-c	80.94a-c
N ₃ P ₂	27.55de	39.53de	51.74g	82.67a-c	79.67a-d
N ₃ P ₃	35.03ab	40.81c-e	71.94bc	83.933a-c	80.23a-c
N ₃ P ₄	36.43a	44.15a-c	67.85b-e	82.63a-c	80.30a-c
N ₄ P ₁	33.50a-c	41.40b-d	62.83de	87.07ab	84.97ab
N ₄ P ₂	28.22d	43.39bc	64.07de	85.30ab	81.67ab
N ₄ P ₃	36.87a	44.65ab	73.54ab	85.29ab	79.13a-d
N ₄ P ₄	37.52a	47.46a	80.22a	89.17a	86.40a
SE (±)	2.52	1.71	3.74	3.57	3.46
P value	<0.01	<0.01	<0.05	<0.05	<0.05
CV (%)	11.15	4.58	7.79	5.88	5.94

Here, SE, p value and CV indicate standard error, level of significance and co-efficient of variation, respectively. N₀= 0, N₁= 52, N₂= 69, N₃= 86, N₄= 104 kg/ha nitrogen. and P₁= Broadcasting, P₂= Line sowing, P₃= Hill sowing and P₄= Transplanting. Different letters in a column indicate the means are statistically different according to Tukey's HSD Test ($p \leq 0.05$).

4.2. Effective tiller

4.2.1. Effect of nitrogen rates

There may be more productive tillers when N fertilizer is applied (Budhar and Palaniappan, 1996; Wilhelm, 1998). But not all tillers make the same contribution to high production (Sahu et al., 2004). The findings of our study showed that the number of tillers m⁻² was significantly influenced by nitrogen rates as shown in Fig. 3. The highest mean number of tillers/m² (853.58) was obtained at 75 DAS from nitrogen level at 86 kg/ha succeeded by 104 kg/ha (813.21) and the lowest (222.83) was observed from the controlled treatment. The significant increase in the

number of tillers per square meter at 86 kg ha⁻¹ nitrogen can be attributed to the optimal supply of nitrogen, promoting both vegetative growth and tiller development. In contrast, the decrease seen at 104 kg N/ha could be a result of excessive nitrogen, which may cause increased competition or stress from lodging (Fageria et al., 2010). There may be more productive tillers when N fertilizer is applied (Budhar and Palaniappan, 1996; Wilhelm, 1998). But not all tillers make the same contribution to high production (Sahu et al., 2004). Controlled areas where nitrogen was not applied showed the lowest number of tillers, attributed to nutrient deficiency, which restricted both plant growth and tillering (Zhang et al., 2020). Similarly, Paul et al. (2017) and Qurashi et al. (2013) found that the nitrogen dose had a substantial impact on the number of tillers hill⁻¹. With the supply of nitrogen, the number of tillers increased. Research conducted by Rajput et al. (1988) indicates that the number of tillers per square meter increases with greater nitrogen absorption by the crop.

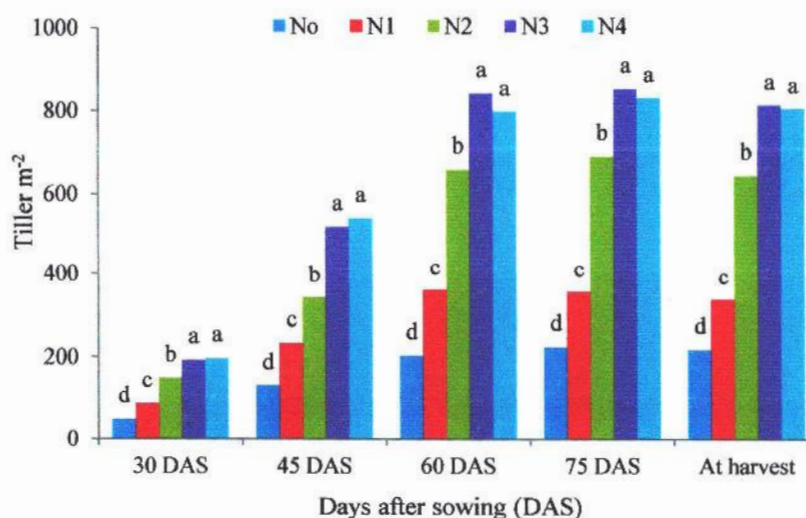


Fig. 3. Tiller no. of late season Aus rice as affected by different nitrogen rates.

Here, $N_0 = 0$, $N_1 = 52$, $N_2 = 69$, $N_3 = 86$ and $N_4 = 104$ kg/ha nitrogen. Different letters on the bar indicate the means are statistically different.

4.2.2. Effect of planting methods

In this study, result showed that the effect of planting methods had significant effect on tiller no of late season aus rice (Fig. 4). The maximum number of tillers m⁻² (688.27) was obtained from the transplanting method followed by the hill sowing (624.47) and line sowing of seed (546.53), respectively for BRRI dhan48 at 75 DAS and minimum tiller no (504.60) from broadcasting (fig. 4) due to uniform spacing and reduced intra-plant competition, which promoted optimal nutrient uptake, aeration, and light interception, as also reported by Satish

(2006). lowest tiller at broadcasting of aus rice due to uneven plant distribution and overcrowding, leading to limited resource availability and suppressed tiller formation (Das et al., 2015). The result is supported by Kour et al., (2018). Akbar et al. (2011) observed similar results in their field experiment. The result found that line sowing method produced significantly the highest effective tillers /hill (16.49) over the broadcast and dibbling methods (Akber et al., 2011). Another field experiment that resulted at harvest time, the transplanted treatments yielded a significantly greater number of tillers m^{-2} and panicle-bearing tillers than the broadcasted treatments, regardless of when they were planted. The treatment with 40 hills m^{-2} produced 421 tillers m^{-2} at harvest, which was statistically equivalent to all transplanted treatments (Sharma et al., 2023) .

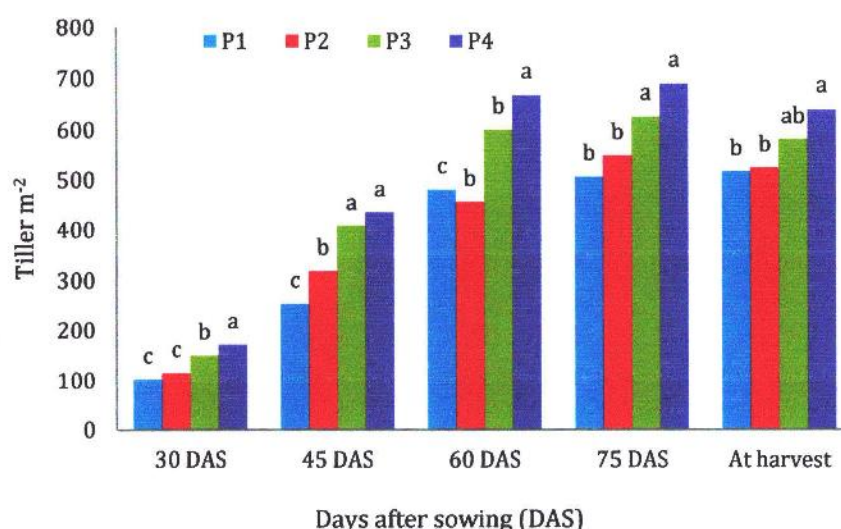


Fig. 4. Tiller no. of late season Aus rice as affected by different planting methods.

Here, P1= Broadcasting, P2= Line sowing, P3= Hill sowing and P4= Transplanting. Different letters on the bar indicate the means are statistically different.

4.2.3. Interaction of nitrogen rates and planting method

The interactive influence of nitrogen application rates and planting techniques had a notable impact on tiller number as shown in Table 3. The highest tiller count per square meter was recorded in the combination of hill sowing with 104 kg of nitrogen per hectare, amounting to 928.22. This was closely followed by transplanting with 86 kg of nitrogen per hectare, which yielded a count of 920.67 at 75 days after sowing. Transplanting and 104 kg ha^{-1} (919.33) nitrogen occupied the third place. Combination of broadcasting with no nitrogen resulted in the lowest tiller no (161.67). Combination of line sowing with no nitrogen resulted in the second lowest tiller no (229.33).

Table 3. Interaction effect of N rates and planting methods on tiller no of late season aus rice grown in the coastal soil of southwestern Bangladesh

Interaction of N rates and planting methods	Tiller no				
	30 DAS	45 DAS	60 DAS	75 DAS	At harvest
N ₀ P ₁	43.33h	60.67g	113.67h	161.67g	152.67g
N ₀ P ₂	46.00h	141.67f	218.00gh	229.33fg	236.00fg
N ₀ P ₃	48.67h	160.00f	232.00f-h	237.00fg	213.33fg
N ₀ P ₄	56.67h	158.67f	245.33fg	263.33fg	260.00fg
N ₁ P ₁	58.00h	172.00ef	328.33e-g	333.33ef	316.00fg
N ₁ P ₂	66.00gh	266.00d	337.33e-g	280.67fg	262.67fg
N ₁ P ₃	69.00fg	241.33de	358.33ef	376.00ef	366e-g
N ₁ P ₄	123.67d-f	247.00de	417.00e	433.33e	405.33d-f
N ₂ P ₁	114.00ef	212.33d-f	566.00d	588.33d	573.33c-e
N ₂ P ₂	149.00b-e	250.67d	593.00d	598.33d	574.00c-e
N ₂ P ₃	153.33b-d	424.00bc	649.00cd	674.00b-d	622.67b-d
N ₂ P ₄	176.67b	479.33b	833.00ab	904.67a	811.67ab
N ₃ P ₁	138.00c-e	357.33c	793.67ab	802.00ab	785.67a-c
N ₃ P ₂	162.67bc	459.67b	749.00bc	784.33a-c	767.67a-c
N ₃ P ₃	222.33a	623.00a	910.00a	907.33a	830.00ab
N ₃ P ₄	244.00a	642.00a	918.27a	920.67a	870.00a
N ₄ P ₁	156.00b-d	463.67b	596.67d	637.67cd	744.67a-c
N ₄ P ₂	148.33b-e	470.67b	830.67ab	840.00a	769.67a-c
N ₄ P ₃	226.67a	587.33a	846.00ab	928.00a	862.00a
N ₄ P ₄	253.33a	643.67a	917.33a	919.33a	843.00ab
SE (±)	17.86	37.43	63.45	67.59	59.46
P value	<0.01	<0.05	Ns	ns	Ns
CV (%)	16.31	12.98	13.57	15.06	12.93

Here, SE, p value and CV indicate standard error, level of significance and co-efficient of variation, respectively. N₀= 0, N₁= 51, N₂= 69, N₃= 86, N₄= 104 kg/ha nitrogen. and P₁= Broadcasting, P₂= Line sowing, P₃= Hill sowing and P₄= Transplanting. Different letters in a column indicate the means are statistically different according to Tukey's HSD Test ($p \leq 0.05$).

4.3. Leaf chlorophyll content index (SPAD value)

4.3.1. Effect of nitrogen rates

Significant ($p < 0.01$) variation of leaf chlorophyll content was found at different growth stages and at harvest with different rates of N fertilizer (Fig. 5). The highest chlorophyll content (46.39) was observed at 45 DAS from the N fertilizer application @150% whereas the lowest (27.48) was found from control treatment (no N added plot) at 75 DAS. Same result was observed by Rajesh et al. (2017). Chlorophyll pigments are crucial for the process of photosynthesis and for biomass generation. Genotypes that maintain high concentrations of

leaf chlorophyll-a and chlorophyll-b during the entire growth period may be considered valuable contributors for the development of increased biomass and improved photosynthetic efficiency. In leaf blades, a higher chlorophyll content enhances the rate of photosynthesis (Sherin et al., 2022; Hassan et al., 2009).

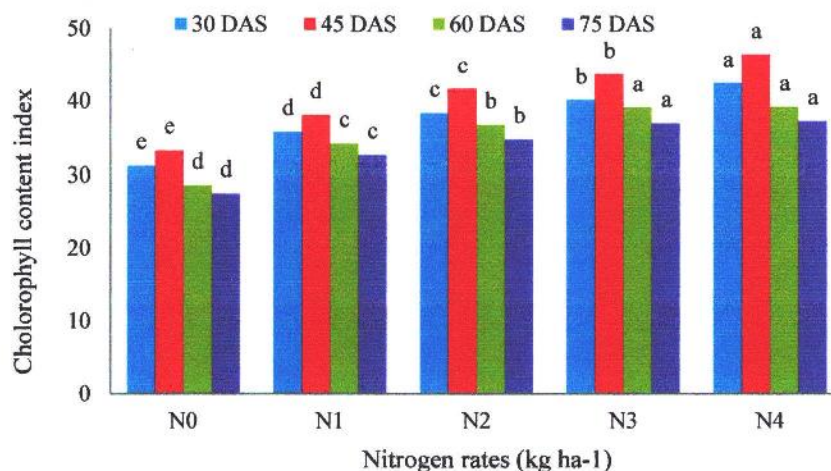


Fig. 5. Leaf chlorophyll content of late season Aus rice as affected by different nitrogen rates. Here, $N_0 = 0$, $N_1 = 52$, $N_2 = 69$, $N_3 = 86$ and $N_4 = 104$ kg/ha nitrogen. Different letters on the bar indicate the means are statistically different.

4.3.2. Effect of planting methods

Significant ($p < 0.01$) variation of leaf chlorophyll content was observed at different growth stages with different planting methods of late season aus rice (Fig. 6). The highest chlorophyll content (41.34) was observed at 45 DAS from the transplanting method whereas the lowest (33.18) was found from the broadcasting method at 75 DAS. Zohora et al. (2023) found a similar result that at 45 DAT, the highest chlorophyll content (35.77) was obtained. The chlorophyll meter (SPAD value) is an easy-to-use, portable diagnostic tool which assesses the degree of greenness or proportional levels of leaves (Netto et al., 2005).

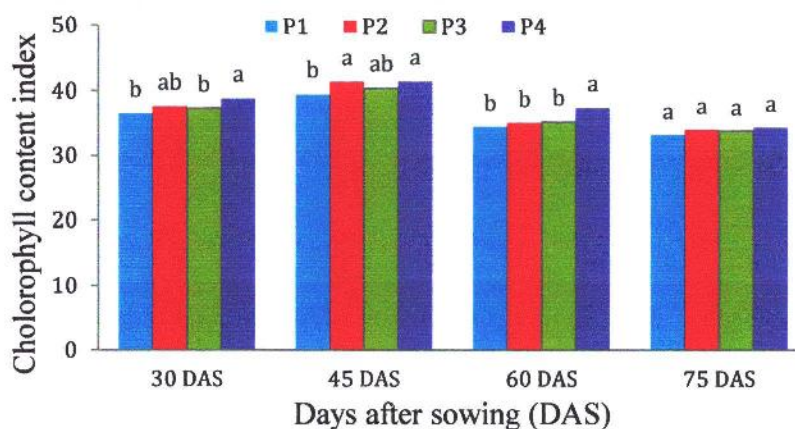


Fig. 6. Leaf chlorophyll content of late season Aus rice as affected by different planting methods.

Here, P1= Broadcasting, P2= Line sowing, P3= Hill sowing and P4= Transplanting. Different letters on the bar indicate the means are statistically different.

4.3.3. Interaction effect of nitrogen rates and planting methods

There was no significant variation of leaf chlorophyll content index (SPAD value) was noticed at the interaction effect of N rates and planting methods (Fig. 9). The highest chlorophyll content (47.77) was observed at 45 DAS from the transplanting method with 150% nitrogen whereas the lowest (26.93) was found from the broadcasting method at 0% nitrogen at 75 DAS. This could have happened because of an adequate supply of light and nutrients for greater spacing with the increased levels of fertilization that were likewise noted by Paul et al. (2017) and Biswas et al. (2016).

Table 4. Interaction effect of N rate and planting method on leaf chlorophyll content index of late season aus rice grown in the coastal soil of southwestern Bangladesh

Interaction of N rates and Planting methods	Leaf chlorophyll content index			
	30 DAS	45 DAS	60 DAS	75DAS
N ₀ P ₁	30.67j	32.23k	27.93i	26.93h
N ₀ P ₂	31.03ij	34.27i-k	29.60hi	29.03gh
N ₀ P ₃	30.70j	33.20k	28.23i	27.00h
N ₀ P ₄	32.40h-j	33.37jk	28.47i	26.97h
N ₁ P ₁	33.87g-i	36.63h-j	33.83fg	33.03d-g
N ₁ P ₂	35.37f-h	39.06f-h	35.08e-g	34.00c-f
N ₁ P ₃	36.33e-g	37.47hi	32.37gh	30.77f-h
N ₁ P ₄	37.40d-e	38.90gh	35.37d-g	32.73e-g
N ₂ P ₁	36.93d-g	39.70e-h	36.00d-f	34.13b-g
N ₂ P ₂	38.70c-e	41.16d-g	36.10d-f	35.20a-f
N ₂ P ₃	38.63c-e	43.17cd	36.67c-f	35.17a-f
N ₂ P ₄	38.93c-e	42.50c-e	38.03c-e	34.47b-f
N ₃ P ₁	39.90b-d	42.87c-e	37.40c-e	35.97a-e
N ₃ P ₂	40.67bc	45.33a-c	37.77c-e	36.10a-e
N ₃ P ₃	38.63c-e	42.30c-f	38.70b-d	37.30a-d
N ₃ P ₄	41.10a-c	44.17b-d	42.17ab	38.17a-c
N ₄ P ₁	41.50a-c	45.60a-c	37.10c-f	35.83a-e
N ₄ P ₂	42.20ab	46.60ab	36.63c-f	35.31a-e
N ₄ P ₃	42.27ab	45.60a-c	40.07a-c	38.50ab
N ₄ P ₄	43.90a	47.77a	42.60a	39.10a
SE (±)	1.53	1.63	1.72	1.18
P value	ns	ns	ns	<0.01
CV (%)	4.98	4.92	5.92	4.28

Here, SE, p value and CV indicate standard error, level of significance and co-efficient of variation, respectively. N₀= 0, N₁= 52, N₂= 69, N₃= 86, N₄= 104 kg/ha nitrogen. and P1= Broadcasting, P2= Line sowing, P3= Hill

sowing and P4= Transplanting. Different letters in a column indicate the means are statistically different according to Tukey's HSD Test ($p \leq 0.05$).

4.4 Effect of nitrogen rates on yield attributes

4.4.1. Panicle m^{-2}

The number of panicles per square meter exhibited significant statistical variation ($p < 0.01$) in relation to various level of nitrogen fertilizer application (Table 5). The maximum panicle m^{-2} count recorded was 777.08 at a nitrogen application rate of 125%, while the lowest effective tiller count of 200.50 was observed at 0% nitrogen. Haque et al. (2015) examined the effects of five N levels (0, 40, 80, 100, and 140 $kg\ ha^{-1}$) and found that the optimal quantity of panicles per hill was achieved with an application of 100 $kg\ ha^{-1}$ nitrogen, with 140 $kg\ ha^{-1}$ nitrogen yielding similar results. Additionally, Mahato et al. (2019) performed a field study using four N levels (0, 80, 100, and 120 $kg\ ha^{-1}$) and determined that the highest number of panicles per square meter (225.0) was reached with nitrogen at 120 $kg\ ha^{-1}$.

4.4.2. Panicle length (cm)

The panicle length exhibited an increase with the rising levels of nitrogen across all treatments. The present finding showed that panicle length was significantly influenced by nitrogen rates as shown in Table 5. The greatest average panicle length, measuring 20.63 cm, was recorded with the application of 125% nitrogen at a rate of 150 kg/ha urea, closely followed by the 150% nitrogen treatment, which yielded a length of 20.52 cm; both results were statistically comparable. The third place was occupied by 100% (19.80 cm) and the least mean (17.34 cm) was noted from control. Results from the previous two were statistically different. This correlation between enhanced nitrogen supply and panicle length was similarly noted by Singh and Sharma (1993). A separate field experiment carried out by Mahato et al. (2019) involved four nitrogen levels and revealed that the maximum panicle length occurred at a nitrogen application rate of 120 $kg\ ha^{-1}$, which contrasts with the results of the current study.

4.4.3. Filled grain and unfilled grain

The quantity of filled grains per panicle varied significantly ($p < 0.01$) with different levels of nitrogen application, as shown in Table 5. N application @ 125% provide the maximum counts of filled grain per panicle (94.83) and the lowest (62.50) was recorded in no nitrogen application. Unfilled grain was the highest (18.50) in control and the lowest (10.50) was in 125% nitrogen treatment. Refey et al., (1989) observed a similar trend with the increase of nitrogen level in rice. According to Akber et al. (2011), the application of nitrogen at a rate of

120 kg per hectare resulted in the highest count of filled grains per panicle at 57.56, a figure that was statistically similar to the 53.89 filled grains per panicle observed with a nitrogen application of 140 kg per hectare. The lowest number of filled grains (46.33) in control plot due to nitrogen deficiency.

4.4.4 1000 grain weight (g)

Effect of different nitrogen rates on 1000 grain weight (g) was highly significant ($p < 0.01$). Numerically the maximum weight (28.90 g) was found at 125% nitrogen level and the minimum (22.09 g) was found in no nitrogen added plot. Identical results were likewise demonstrated by Manzoor et al., (2006), Salem et al., (2011), and Youseftabar et al., (2012). Elevated nitrogen levels contributed to an increase in grain weight, attributed to the higher chlorophyll content in the leaves, which subsequently enhanced the photosynthesis process during the grain development phase (Manzoor et al., 2006).

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

The varying levels of nitrogen application have a considerable impact on grain yield. The maximum yield recorded was 3.64 t ha^{-1} at 125% nitrogen (N_3), while the control treatment yielded the lowest at 1.35 t ha^{-1} (Fig. 7). Chaturvedi (2005) noted that nitrogen plays a crucial role in enhancing protein content, which subsequently increases grain weight. The grain yield was notably influenced by the interaction of various yield components, including the count of productive tillers, the length of the panicle, the proportion of filled grains, and the weight of 1000 grains (Li et al., 2019). Research indicates that this primary yield component is significantly impacted by both nitrogen rates and the planting methods (Sarker et al., 2020).

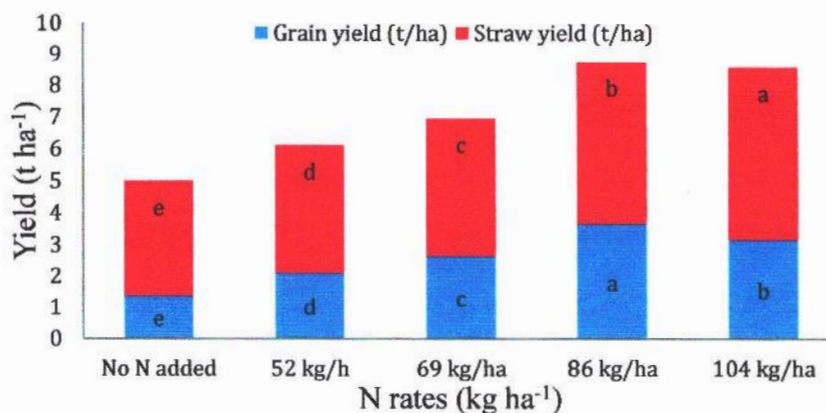


Fig. 7. Grain yield and straw yield of late season Aus rice as affected by different nitrogen rates. Different letters on the bar indicate the means are statistically different where, $SE = 0.04$ and 0.08 , respectively. Here, $N_0 = 0$, $N_1 = 52$, $N_2 = 69$, $N_3 = 86$ and $N_4 = 104 \text{ kg/ha}$ nitrogen.

4.4.6. Straw yield (t ha⁻¹)

Nitrogen levels significantly influence the straw yield ($p < 0.01$). The highest straw yield, measuring 5.42 t ha⁻¹, was noted with a nitrogen application rate of 150%, whereas the lowest yield of 3.64 t ha⁻¹ was found in the control area (N₀), as demonstrated in Figure 7. A study conducted by Alim (2012) demonstrated that increasing the nitrogen rate from 120 kg ha⁻¹ resulted in enhanced grain and straw yields.

4.4.7. Harvest Index (%)

The different levels of N application have significant effect on the harvest index. Significantly ($p < 0.01$) differed with the variation of N fertilizer rates has considerable effect on harvest index (Table 5). Nitrogen fertilizers @125% was found the highest harvest index (41.61%) followed by @100% (37.48%) which was identical to @150% at 150 kg/ha urea indicates that optimal nitrogen availability enhances the partitioning of assimilates towards grain production, improving yield efficiency (White and Wilson, 2006) whereas the lowest (27.13%) was recorded from control treatment (no N applied) plots due to limited nitrogen availability, which restricted vegetative growth and reproductive output, consistent with findings by Dobermann and Cassman (2005) and Fageria (2014), who highlighted the critical role of nitrogen in improving grain yield and harvest index in cereals.

Table 5. Yield and yield components of late season aus rice grown in the coastal soil of southwestern Bangladesh as affected by different nitrogen rates.

N rates (kg ha ⁻¹)	Panicle m ⁻² (no.)	Panicle length (cm)	Filled grain panicle ⁻¹ (no.)	Unfilled grain panicle ⁻¹ (no.)	1000-grain weight (g)	Harvest index (%)
N ₀	200.50d	17.34c	62.50d	18.50a	22.09d	27.13d
N ₁	321.83c	19.21b	72.17c	12.75b	24.06c	33.69c
N ₂	561.42b	19.80b	87.17b	11.67b	26.06b	37.48b
N ₃	777.08a	20.63a	94.83a	10.50b	28.90a	41.61a
N ₄	771.17a	20.52a	82.50b	11.17b	26.56b	36.72b
SE (±)	22.45	0.33	2.92	1.28	0.73	0.48
p value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CV (%)	10.45	4.09	8.97	24.36	7.04	3.30

Here, SE, p value and CV indicate standard error, level of significance and co-efficient of variation, respectively. N₀= 0, N₁= 52, N₂= 69, N₃= 86 and N₄= 104 kg/ha nitrogen, respectively. Different letters in a column indicate the means are statistically different according to Tukey's HSD Test ($p \leq 0.05$).

4.5 Effect of planting methods on yield attributes

4.5.1. Panicle m⁻²

Number of panicle m⁻² with different planting methods was statistically ($p < 0.01$) differed (Table 6) where maximum effective tiller number (599.40) was found at transplanting method and the minimum effective tiller number (448.40) was found at broadcasting method. Second lowest panicle was around at hill sowing. The highest density of panicles per square meter was achieved through the transplantation of rice reported by Sorour et al., (2016). This was primarily because of the highest quantity of tillers at different growth stages in conventional transplanting as opposed to broadcasting. The identical outcome was achieved by Ali et al. (2013).

4.5.2. Panicle length (cm)

The present finding showed that panicle length was influenced significantly by nitrogen rates. Effect of planting method on the yield and yield component of BRRI dhan48 are presented in Table 6. The highest mean panicle length (19.99 cm) was achieved through transplanting, which was subsequently followed by hill sowing (19.52 cm), as more spacing produce more grains per panicle due to higher sunlight, moisture and nutrient achievement (Alam et al., 2012) and the lowest mean (19.03 cm) was obtained through broadcasting. Results from the previous two were statistically different.

4.5.3. Filled grain and unfilled grain

The various planting methods exhibited a statistically significant effect ($p < 0.01$) on the number of filled grains per panicle, resulting in notable variations (Table 6). Transplanting methods provide the highest number of filled grain per panicle (96.13) and the lowest (67.53) was recorded in the broadcasting method. Unfilled grain was highest (15.07) in control and lowest (10.93) was in the transplanting method. An experiment conducted by Sorour et al., (2016) discovered that the transplanting method resulted in the highest quantity of filled grains per panicle. The higher count of filled grains per panicle in transplanted rice can be linked to enhanced light intensity, suitable spacing, and efficient movement of photosynthetic products to the spikelets. A similar finding was reported by Sekhar et al. (2014).

4.5.4 1000-grain weight (g)

Effect of different planting methods on 1000 grain weight (g) was highly significant ($p < 0.01$). Numerically the maximum weight (27.33 g) was found at transplanting followed by hill sowing (25.64 g) and the minimum (23.91 g) was found in broadcasting method. The observed phenomenon may be attributed to the enhanced growth of plants during transplanting, which is facilitated by consistent spacing. This conclusion aligns with the findings reported by Ehsanullah et al. (2000).

4.5.5. Grain yield (t ha⁻¹)

The present study showed that grain yield was significantly influenced by the nitrogen rates as shown in Fig. 8. The maximum grain yield (2.99 t ha⁻¹) was observed during transplanting, while the minimum yield (2.16 t ha⁻¹) occurred with broadcasting. These results align closely with the findings presented by Javaid et al. (2012).

4.5.6. Straw yield (t ha⁻¹)

The effect of planting methods on straw yield varied significantly ($p < 0.01$). The maximum straw yield (4.67 t ha⁻¹) was recorded at line sowing and the minimum (4.37 t ha⁻¹) was found in transplanting (Fig. 8). A similar result was found by Rayhan (2015).

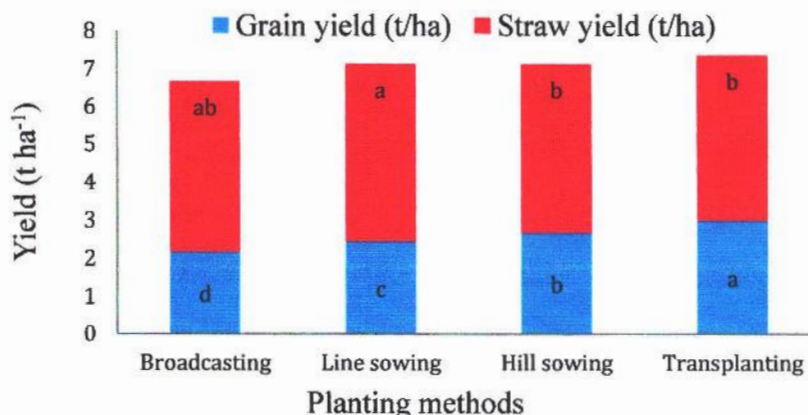


Fig. 8. Grain yield and straw yield of late season Aus rice as affected by different planting methods. Different letters on the bar indicate the means are statistically different.

4.5.7. Harvest Index (%)

The different planting methods have significant effect on the harvest index. Significantly ($p < 0.01$) differed with the variations of planting methods has considerable effect on harvest index (Table 6). The highest harvest index (39.84%) was found from transplanting followed by hill sowing (36.45%) whereas the lowest (31.66%) was recorded from broadcasting

methods. The superiority of transplanting over broadcast seeding may be attributed to the improved establishment and growth of rice plants. San-oh et al., (2004) found the same thing.

Table 6. Yield and yield components of late season aus rice grown in the coastal soil of southwestern Bangladesh as affected by different planting methods.

Planting method	Panicle m ⁻² (no.)	Panicle length (cm)	Filled grain panicle ⁻¹ (no.)	Unfilled grain panicle ⁻¹ (no.)	1000-grain weight (g)	Harvest index (%)
P ₁	448.40c	19.03b	67.53d	15.07a	23.91c	31.66d
P ₂	560.53ab	19.46ab	73.00c	13.53ab	25.20bc	33.36c
P ₃	512.53b	19.52ab	82.67b	12.13bc	25.64b	36.45b
P ₄	599.40a	19.99a	96.13a	10.93c	27.33a	39.84a
SE (±)	20.08	0.29	2.61	1.15	0.66	0.43
p value	<0.01	<0.05	<0.01	<0.05	<0.01	<0.01
CV (%)	10.45	4.09	8.97	24.36	7.04	3.30

Here, SE, p value and CV indicate standard error, level of significance and co-efficient of variation, respectively. P₁= Broadcasting, P₂= Line sowing, P₃= Hill sowing and P₄= Transplanting, respectively. Different letters in a column indicate the means are statistically different according to Tukey's HSD Test ($p \leq 0.05$).

4.6. Interaction effect of nitrogen rates and planting method

4.6.1. Panicle m⁻²

Number of panicle/m² with different planting methods was statistically ($p < 0.01$) differed (Table 7) whereas maximum panicle number (847.33) was found at transplanting method with 125% nitrogen and the minimum panicle number (140.00) was found at broadcasting method with control treatment. The highest density of panicles per square meter was achieved through the transplantation of rice. This outcome can be primarily attributed to the greater number of tillers observed at various growth stages in the regular transplanting method, in contrast to broadcasting. A similar finding was reported by Ali et al., (2013). Furthermore, an increase in the nitrogen application rate to 103.5 kg/ha resulted in a significant rise in the number of panicles per square meter. This enhancement in panicle density due to nitrogen application is largely linked to nitrogen's role in promoting cell division, which in turn facilitates tiller development. Additionally, the increased availability of nitrogen is crucial for panicle formation during the rice production phase. Abd El Hamed, (2002) also noted an amplified effect of nitrogen on the number of panicles per square meter.

4.6.2. Panicle length (cm)

The present finding showed that Interaction effect of variety and different nitrogen rates had no significant influence on panicle length of late season aus rice. Interaction effect of planting

method on the yield and yield component of BRRI dhan48 are presented in Table 7. Rayhan (2015) found same result that the interaction of planting methods and N-splitting had no significant influence on panicle length.

4.6.3. Filled grain and unfilled grain panicle⁻¹

With the different levels of nitrogen application and planting method number of filled grain per panicle was varied statistically ($p < 0.05$). The interaction has significant effect on number of filled grain per panicle (Table 7). N application @ 125% with transplanting provide the highest number of filled grain per panicle (111.00) and the lowest (48.67) was recorded at no nitrogen application with broadcasting method. Unfilled grain was the highest (27) at broadcasting with control method and lowest (7.00) was at transplanting with 125% nitrogen. These results closely align with those published by Sekhar et al., (2014). The application of 150 kg of nitrogen per hectare to transplanted plants resulted in the highest recorded values for the number of filled grains per panicle in a separate field experiment conducted by Sorour et al., (2016). On the contrary, were found in broadcasts that did not apply nitrogen fertilizer had the lowest values.

4.6.4 1000 grain weight (g)

Interactive impact of varying nitrogen rates with different planting methods on 1000 grain weight (g) was significant ($p < 0.05$). Numerically the maximum weight (31.39 g) was found at 125% nitrogen level with transplanting method and the minimum (21.31 g) was found in no nitrogen added broadcasting plot. This is mostly because plants that receive nitrogen at any rate have more spikelets per panicle than plants that do not receive any nitrogen. Because the source is limited and the sink capacity is high, there was a greater loading of grains, which led to a higher grain weight. Metwally et al. (2010) reported the boosting effects of nitrogen on 1000-grain weight.

4.6.5. Grain yield (t ha⁻¹)

The present study showed that grain yield was significantly ($p < 0.01$) influenced by the nitrogen rates as shown in Fig. 9. The maximum grain yield of 4.06 t ha⁻¹ was observed during transplanting with a nitrogen application of 125% (N3), while the minimum yield of 1.19 t ha⁻¹ occurred with the control treatment under broadcasting. An experiment by Sorour et al., (2016) indicated that applying 150 kg N ha⁻¹ to transplants resulted in the highest grain yield values. Conversely, the lowest yields were recorded from broadcasted treatments that did not include nitrogen fertilizer. The soil of the experimental field was poor in N content. Hence

better result were found from higher dose of N. These results align closely with the findings of Chen et al. (2014).

4.6.6. Straw yield (t ha^{-1})

The interactive impact of nitrogen rates and planting method on straw yield varied significantly ($p < 0.01$). The maximum straw yield (5.92 t ha^{-1}) was recorded at broadcasting with 150% N can be attributed to the enhanced vegetative growth due to higher nitrogen availability and more plant density and the minimum (3.05 t ha^{-1}) was obtained through transplanting with 0% nitrogen added area (P_4N_0) (Fig. 9) due to less plant density. Similar result was found by Rayhan (2015). Increased nitrogen enhanced photosynthesis and various physiological functions, thereby promoting biomass growth.

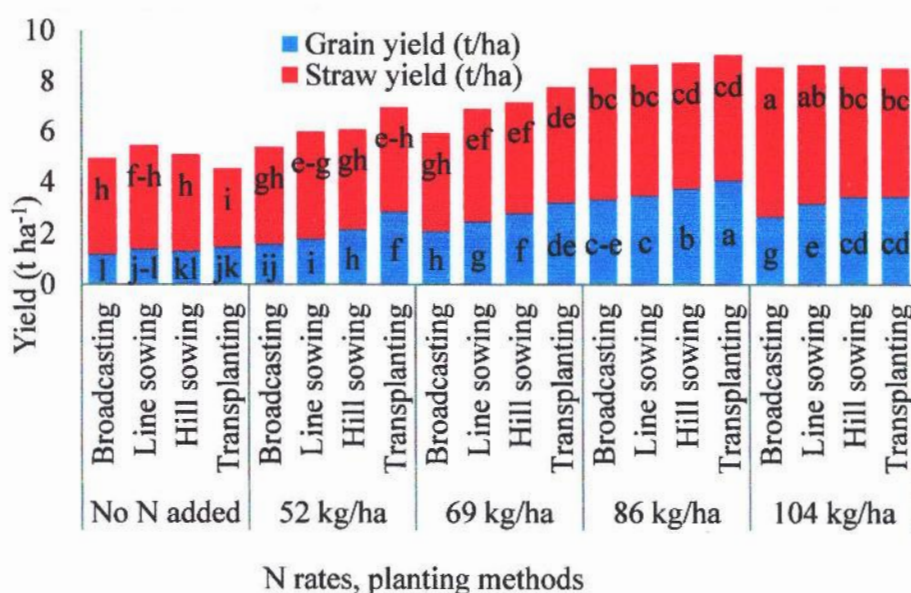


Fig. 9. Grain yield and straw yield of late season Aus rice as affected by interaction of different nitrogen rates and different planting methods. Different letters on the bar indicate the means are statistically different.

4.6.7. Harvest Index (%)

The interaction of planting method and varying doses of N have significant effects on the harvest index. Significantly ($p < 0.01$) differed with the variation of interaction of planting methods with N fertilizer rates has considerable effect on harvest index (Table 7). Transplanting with nitrogen fertilizers @125% was found the highest harvest index (44.99%) followed by hill sowing @125% (42.78%) whereas the lowest (24.24%) was recorded from broadcasting with control treatment (no N applied) plots. Transplanting with 125% nitrogen (equivalent to 187.5 kg/ha urea) yields the highest harvest index because it efficiently balances

plant uptake and nitrogen delivery, promoting vegetative and reproductive growth. At 150% (225 kg/ha urea), too much nitrogen leads to excessive vegetative growth, which reduce grain yield and lower the harvest index. The enhanced harvest index may result from the healthier and more vigorous growth of plants, taller plant heights, elevated crop growth rates, and higher net assimilation rates, which ultimately led to the increased harvest index. The results are comparable to those obtained by Abid et al. (2015).

Table 7. Yield and yield components of late season aus rice grown in the coastal soil of southwestern Bangladesh as affected by interaction of nitrogen rates and different planting method.

Interaction of N rates and Planting methods	Panicle/m ² (no.)	Panicle length (cm)	Filled grain panicle ⁻¹ (no.)	Unfilled grain panicle ⁻¹ (no.)	1000-grain weight (g)	Harvest index (%)
P ₁ N ₀	140.00g	16.17f	48.67h	27.00a	21.31f	24.24j
P ₂ N ₀	204.00fg	17.17ef	60.67f-h	18.00ab	22.30f	25.58j
P ₃ N ₀	201.33fg	18.12c-f	58.33gh	15.00bc	21.63f	26.14j
P ₄ N ₀	256.67e-g	17.90d-f	82.33c-f	14.00bc	23.13ef	32.55gh
P ₁ N ₁	310.67ef	19.60a-e	66.67e-h	14.67bc	24.20c-f	29.57i
P ₂ N ₁	240.33e-g	18.87a-e	71.67e-g	13.00bc	24.94b-f	29.70i
P ₃ N ₁	337.67ef	18.60b-f	67.67e-h	11.00bc	23.33d-f	35.02fg
P ₄ N ₁	398.67de	19.77a-d	82.67c-f	12.33bc	23.79d-f	40.46b-d
P ₁ N ₂	330.67ef	19.57a-e	75.33d-g	11.67bc	25.34b-f	34.89fg
P ₂ N ₂	574.67cd	20.07a-d	76.67d-g	13.00bc	25.28b-f	35.24f
P ₃ N ₂	606.33bc	19.47a-e	97.00a-d	11.33bc	24.78c-f	38.59de
P ₄ N ₂	774.00ab	20.10a-d	99.67a-c	10.67bc	28.85a-d	41.20bc
P ₁ N ₃	738.67ab	19.47a-e	80.67c-f	11.00bc	25.66b-f	38.84c-e
P ₂ N ₃	722.33ab	20.87ab	81.33c-f	13.00bc	28.19a-e	39.85cd
P ₃ N ₃	800.00a	21.00ab	106.33a	10.67bc	30.36ab	42.78ab
P ₄ N ₃	847.33a	21.00a	111.00a	7.33c	31.39a	44.99a
P ₁ N ₄	722.00ab	20.37a-d	66.33e-h	11.00bc	23.36d-f	30.77hi
P ₂ N ₄	733.33ab	20.33a-d	74.67e-g	10.67bc	25.30b-f	36.41ef
P ₃ N ₄	824.00a	20.40a-c	84.00b-e	12.67bc	28.09a-e	39.70cd
P ₄ N ₄	805.33a	20.97ab	105.0ab	10.33bc	29.50a-c	40.03cd
SE (±)	44.90	0.65	5.84	2.57	1.47	0.95
P value	<0.01	ns	<0.05	<0.05	<0.05	<0.01
CV (%)	10.45	4.09	8.97	24.36	7.04	3.30

Here, SE, p value and CV indicate standard error, level of significance and co-efficient of variation, respectively. ns indicate statistically nonsignificant. N₀= 0, N₁= 52, N₂= 69, N₃= 86, N₄= 104 kg/ha nitrogen. and P₁= Broadcasting, P₂= Line sowing, P₃= Hill sowing and P₄= Transplanting, respectively. Different letters in a column indicate the means are statistically different according to Tukey's HSD Test ($p \leq 0.05$).

4.7. Relationship between grain yield (t ha^{-1}) and straw yield (t ha^{-1})

When grain yield of BRRI dhan48 was plotted against corresponding straw yield, a linear relation was found ($y = 0.9523x - 1.723$, $R^2 = 0.61$, $p < 0.05$). The grain yield was positively related to straw yield (Figure 10). The grain yield of aus rice exhibited a consistent rise in correlation with the increase in straw yield. The higher value of R^2 indicated that 61% in the variation in grain yield could be explained by the variation in straw yield.

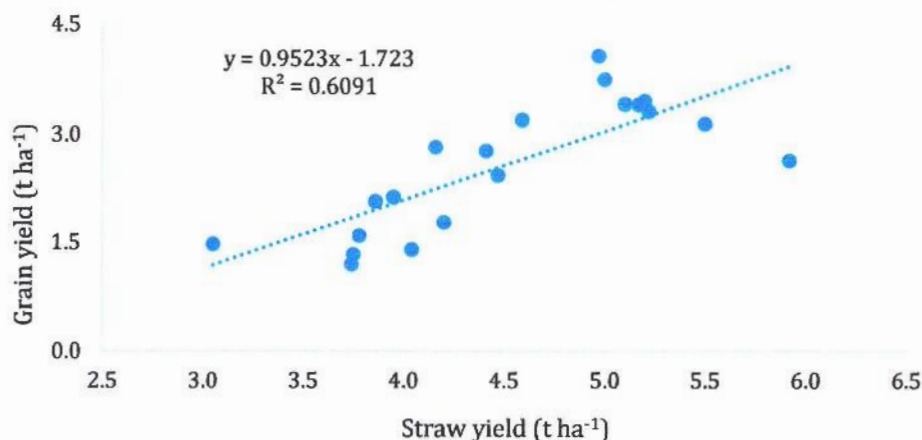


Fig. 10. Relationship of grain yield (t ha^{-1}) with straw yield (t ha^{-1}) of BRRI dhan48.

4.8. Relationship between grain yield (t ha^{-1}) and biological yield (t ha^{-1})

The relationship between seed grain yield (t ha^{-1}) and biological yield (t ha^{-1}) was also found linear and positive (Figure 11). The grain yield (t ha^{-1}) increased steadily with the increase of biological yield (t ha^{-1}). The linear relationship was estimated strong and 91% of the variation in grain yield could be explained by the variation in biological yield of BRRI dhan48 ($y = 0.5554x - 1.3602$, $R^2 = 0.9115$, $p < 0.05$).

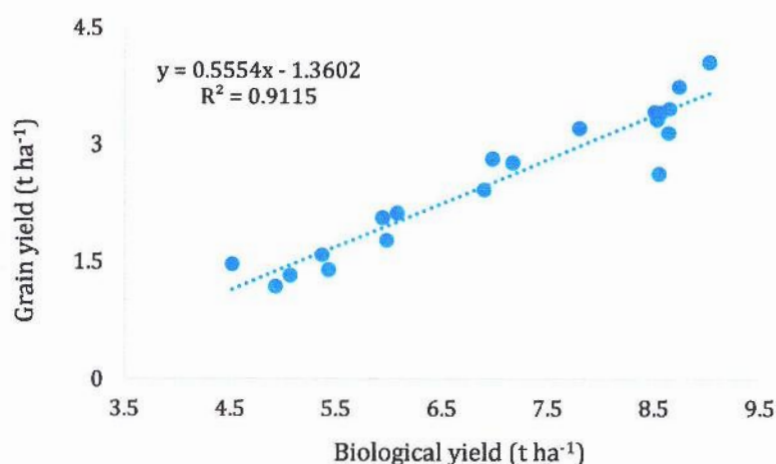


Fig. 11. Relationship of grain yield (t ha^{-1}) with biological yield (t ha^{-1}) of BRRI dhan48.

4.9. Relationship between grain yield (t ha^{-1}) and harvest index (%)

Plotting grain yield of BRRI dhan48 against harvest index (%) resulted a linear but positive relationship (Figure 12). The grain yield increased steadily with the increase of harvest index (%). It is important to highlight that 86% of the variability in grain yield can be attributed to the variability in harvest index, as indicated by the equation $y = 0.1372x - 2.2801$, with an R^2 value of 0.856 where $p < 0.05$.

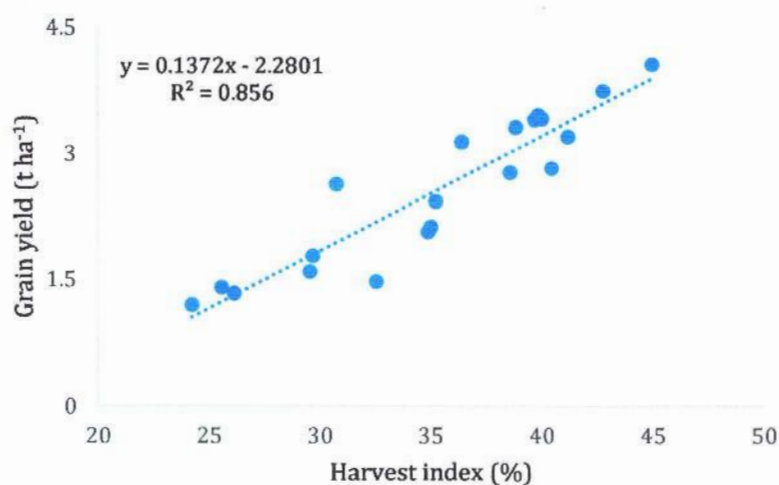


Fig. 12. Relationship of grain yield (t ha^{-1}) with harvest index (%) of BRRI dhan48.

CHAPTER V

SUMMARY AND CONCLUSION

During the period of 08 June 2023 to 20 September 2023, a field experiment was conducted at the Professor Dr. Purnendu Gain Field Laboratory within the Agrotechnology Discipline to investigate the effects of varying nitrogen fertilizer rates and diverse planting methods on the growth and yield of late-season aus (BRRI dhan48) in the southwestern region of Bangladesh. The experiment consisted of five different N fertilizer (0, 75, 100, 125 and 150% of kg urea ha⁻¹ added) and four different planting methods (broadcasting, line sowing, hill sowing and transplanting). The design of the experiment was double factor Randomized Complete Block Design (RCBD) with three replications. Information regarding growth and yield factors, encompassing various plant characteristics, was gathered at the time of harvest and statistically examined, with mean differences assessed using Tukey's HSD test.

Experimental findings indicated that various plant growth and yield-related traits, including plant height, number of tillers, chlorophyll content index, effective tillers per hill, grains per panicle, length of panicles, filled grains per panicle, grain yield, straw yield, biological yield, and harvest index, were notably affected by the differing nitrogen levels and planting methods, with the exception of spad value.

The highest mean plant height (86.78 cm), leaf chlorophyll content index (46.39) was obtained at @150% nitrogen but tiller no (853.58), panicle m⁻² (777.08), panicle length (20.63 cm), filled grain panicle⁻¹ (94.83), grain yield (3.64 t ha⁻¹) and harvest index (41.61%) were obtained from 125% nitrogen. The lowest value of plant height (51.38 cm), tiller no (222.83), chlorophyll content index (27.48), effective tiller m⁻² (200.50), panicle length (17.34 cm), filled grain panicle⁻¹ (62.50), grain yield (1.35 t ha⁻¹) and harvest index (27.13%) were obtained from the control treatment.

The highest mean plant height (76.75 cm), tiller no (688.27), chlorophyll content index (41.34), panicle no m⁻² (599.40), panicle length (19.99 cm), filled grain panicle⁻¹ (96.13) grain yield (2.99 t ha⁻¹) and harvest index (39.84%) were obtained from transplanting method. The lowest value of plant height (70.17 cm), tiller no (504.60), chlorophyll content index (33.18), effective tiller m⁻² (448.40), panicle length (19.03 cm), filled grain panicle⁻¹ (67.53), grain yield (2.16 t ha⁻¹) and harvest index (31.66%) were obtained from the broadcasting method. The highest straw yield (4.67 t ha⁻¹) was observed with the line sowing method, whereas the lowest yield (4.37 t ha⁻¹) was noted in the transplanting method.

Interaction between planting methods and nitrogen rates significantly influenced all growth and yield attributes except for tiller no, chlorophyll content index and panicle length. Combination of transplanting method and 150% N produced the highest tallest plants height (89.17 cm) and chlorophyll content index (47.77). Maximum tiller no (928.22) was observed in hill sowing method with 150% nitrogen. Highest panicle m^{-2} (599.40) filled grain panicle⁻¹ (111.00), grain yield (4.06 t ha⁻¹) and superior harvest index (44.99 %) were obtained from transplanting with 125% nitrogen. Combination of broadcasting with 0 kg N/ha produced the minimum yield and harvest index. The findings of the present study indicate that transplanting and 86.25 kg N/ha (N₃) performed better in the coastal region of southwestern Bangladesh for late season aus rice in terms of growth and yield. So, we can conclude that the transplanting method, combined with 125% of the recommended N dose, is the most effective approach for late season aus rice cultivation in the southwestern coastal region of Bangladesh.

There is significant potential for aus rice cultivation in Bangladesh. The government ought to guarantee that quality seeds are provided in a timely manner and at an affordable price, along with regulating the supply and availability of contaminated fertilizers in the market. Greater emphasis must be placed on developing new varieties with shorter lifespans, resilience to stress, and additional traits. The study was carried out in the southwestern coastal area of Bangladesh. To extrapolate the findings, analogous studies might be performed in various regions of the country. Additional research can be pursued as a priority since soil fertility levels and the efficacy of nitrogen and planting techniques may differ from one location to another and across different seasons in Bangladesh.



CHAPTER VI

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APPENDIX 1

Weather parameters during experimental period

Month	Minimum temperature (°C)	Maximum temperature (°C)	Rainfall (mm)	Humidity (%)
June	27.5	34.7	228	81.11
July	27.4	33.9	150	84.53
August	26.7	32.7	300	92.66
September	27.4	32.3	266	86.97