PRODUCTIVITY AND GRAIN PROTEIN STATUS OF TRANSPLANTED AMAN RICE AS INFLUENCED BY THREE MAJOR AGRONOMIC PRACTICES UNDER SUBTROPICAL CONDITIONS

ROY, T. R.[1] – SARKAR, M. A. R.[1] – KABIRAJ, M. S.[1] – SARKER, U. K.[1] – RASHID, M. H.[1] – HASHEM, A.[2] – AVILA-QUEZADA, G. D.[3] – ABD_ALLAH, E. F.[4] – PAUL, S. K.[1*]

[1]*Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh (e-mails: roytonima32@gmail.com – T. R. Roy; ar.sarkar@yahoo.com – M. A. R. Sarkar; msojibinfo@gmail.com – M. S. Kabiraj; uttam@bau.edu.bd – U. K. Sarker; mhrashid@bau.edu.bd – M. H. Rashid)*

[2]*Botany and Microbiology Department, College of Science, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia (e-mail: habeer@ksu.edu.sa)*

[3]*Facultad de Ciencias Agrotecnológicas, Universidad Autónoma de Chihuahua, 31350 Chihuahua, Chihuahua, México (e-mail: gdavila@uach.mx)*

[4]*Plant Production Department, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia (e-mail: eabdallah@ksu.edu.sa)*

**Corresponding author*
e-mail: skpaul@bau.edu.bd

(Received 12th Sep 2023; Accepted 16th Nov 2023)

Abstract. The aim of this study was to investigate the yield and protein in grains of two high yielding varieties (HYV) transplanted Aman rice. The trial included two assortments viz. BRRI dhan62 and BRRI dhan66; three spacing's viz. 25 cm × 15 cm, 20 cm × 15 cm and 20 cm × 10 cm; and four nitrogen doses viz. 0, 60, 80 and 100 kg/ha. The study was conducted with randomized complete block design (RCBD) and the replication was three. At 70 DAS the tallest plant (126.40 cm), tillers/hill (11.00) and dry matter/hill (21.89 g) were delivered in association of BRRI dhan66 × spacing (25 cm × 15 cm) × fertilizer 100 kg N/ha. The most noteworthy leaf area index (1.16) was recorded in BRRI dhan66 × spacing (25 cm × 15 cm) × fertilizer 100 kg N/ha. The highest productive tillers/hill (7.33), longest panicle (23.74 cm), grains/panicle (129.3), weight of 1000-grain (26.50 g), grain (4.52 t/ha), straw (5.92 t/ha) yields and grain protein content (12.32%) were raised in BRRI dhan66 × spacing (25 cm × 15 cm) × fertilizer 100 kg N/ha. The most elevated harvest index was found (47.72%) in BRRI dhan66 × spacing (20 cm × 10 cm) × fertilizer 60 kg N/ha. BRRI dhan66 with 25 cm × 15 cm planting and treated with 100 kg N/ha was the most promising interaction for enhancing yield and protein status of grains.
Keywords: *variety, spacing, fertilization, yield, quality*

Introduction

Rice (*Oryza sativa* L.) holds critical rural worth as a grain that is involved in the diet of Asia, as well as a huge number of individuals in Africa and Latin America (Maqsood et al., 2013). With a 40.6% employment rate and 11.61% GDP contribution, agriculture is by far the largest producing sector in the economy of Bangladesh (BBS, 2022). Bangladesh is one of the world's significant rice delivering nations, positioning as the third biggest grain producer in the world (FAO, 2022). The Aman rice harvest is second only to Boro rice in terms of production volume. Since rice is so heavily relied upon, its output must rise by roughly 5×10^6 ton per year just to keep up with population growth (IRRI, 1997). Due to the limited amount of available land and high population density, the actual yield of rice is far lower than anticipated, making horizontal growth impossible. There is no room for additional expansion of the rice field in order to achieve the projected rice cultivation. Modern production technologies include planting procedures, high-quality seeds, high yielding types, the ideal seedling age, spacing of planting, plant defense techniques, and seedling grown methods should be employed to maximize yield.

The most effective technique to boost Aman rice yield is through good management practices. For high production, great flavor, and a high rate of return on investment, rice producers must grow a variety of cultivars in various seasons. Significant focus should be placed on the establishment of novel varieties and their management, notably the use of nitrogenous fertilizer and appropriate spacing, to augment the yield per unit region and address changed issues. Variety is a crucial genetic element that helps rice plants produce larger yields. The best ways to increase the output of transplant Aman rice are better crop management and improved cultivars. This is brought on by variations in genetic make-up, dietary needs, growth processes, and environmental factors.

When transplanting rice, plant spacing is a crucial element that must be taken into ac-count. Plants can utilize sunlight and nutrients more effectively when they are spaced apart (Paul et al., 2017). Under conditions of dense planting, rice plants fight with one another for re-sources like sunlight, air, water, nutrients, and space as well as processes like photosynthesis and respiration. At the point when plants are dispersed suitably, factors including a huge leaf area index (LAI), light interferences, and different components are better for rice yield and photosynthesis. Ideal plant dividing guarantees that plants fill appropriately in both their aeronautical and underground parcels through effective use of supplements and sun radiation sections (Islam et al., 2007; Mohaddes et al., 2011).

Nitrogen, an essential plant nutrient, has a substantial impact on the phenology, quantitative and qualitative characters of rice. Nitrogen is a vital nutrient that is involved in many physiological processes and has an impact on rice grain production (Khatun et al., 2023). It has a key role in cell proliferation, which increases yield, and is a component of protoplasm, protein, and chlorophyll. Lower nitrogen fertilizer rates cause plants to lodge, extend their growing season, mature later, become more susceptible to pests and diseases, and eventually produce less. Overuse of nitrogen (N) fertilizer on rice fields pollutes the environment, increases the expense of rice cultivation, reduces grain yield, and contributes to global warming (Peng et al., 2010). Utilizing fertilization to promote optimal yields in line with crop nutrient requirements ensures sustainable rice production and the most economical use of land (Tayefeh et al., 2018). Again, nitrogen is essential for enhancing the protein content of the grains.

Protein content is a crucial indicator of rice grain quality as it increases the amount of whole grain or head rice and makes the grain more resistant to abrasive milling. Given that rice is the primary source of protein in South Asian nations, it is also significant in terms of the nutrients that people consume. A slight expansion in grain protein content will support day to day protein utilization since rice is the locale’s essential day to day energy source and is consumed in remarkably enormous amounts (Chandel et al., 2010). In typical Bangladeshi diet, rice continues to be the main source of protein and calories. In 2318 kcal, rice accounts for 69% of the calories and 50% of the protein (Hussain, 2010).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

To enrich production and grain protein content of two high yielding varieties of Aman rice, the research was conducted to decide the suitable plant spacing and nitrogen level.

Materials and methods

Site, soil and weather status

Between June 2016 and October 2016, the trial was completed at the Agronomy Field Laboratory at the Bangladesh Agricultural University, which is located at 24°75' N latitude and 90°50' E longitude. The region has non-calcareous grey soils and is in Agro-ecological Zone 9 (UNDP and FAO, 1988). The field had a silty-loam texture and a low organic matter content (1.29%). The land was medium high with pH 6.8. In April through September (kharif season), the experimental location experiences high temperatures, high humidity, and significant rainfall with sporadic gusts of wind, while in October through March (rabi season), there is little rainfall and a mild drop in temperature. Climatic data viz. temperature, relative humidity, precipitation, and sunshine hours are provided in (*Fig. 1*).

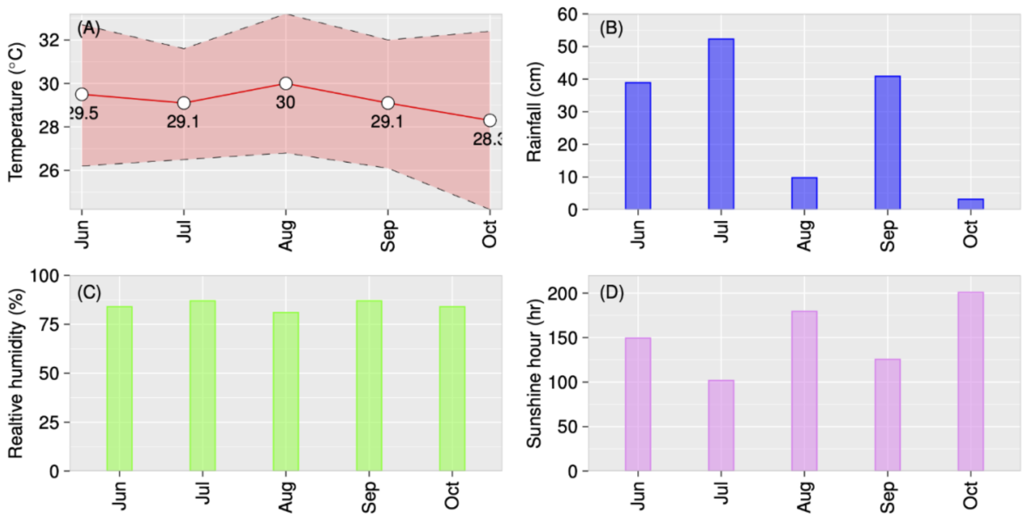

Figure 1. *Temperature, rainfall, relative humidity and sunshine hour condition in crop growing period*

Experimental treatments and design

Two cultivars viz. BRRI dhan62 and BRRI dhan66, three spacing viz. 25 cm × 15 cm, 20 cm × 15 cm, and 20 cm × 10 cm as well as four N doses viz. 0, 60, 80 and 100 kg/ha were used in the study. The varieties used as treatment in this study are Aman and developed by Bangladesh Rice Research Institute (BRRI). They are registered by Seed Certification Agency (SCA) and widely cultivated variety in Bangladesh. The doses of N levels that was used in this study is commonly applied rates for the variety and other doses used as treatment in this study. The design of study consisted of a factorial randomized full block and it had three replications. A sum of 24 unit plots were made out of each block, and each one was randomly assigned one of 24 distinct treatment combinations. 72 unit plots made up the experiment. A 2.5 m by 2 m unit plot was used. There was a 50 cm and a 1 m gap between each plot and block.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

Crop husbandry

Bangladesh Rice Research Institute provided the BRRI dhan62 and BRRI dhan66 for this study. Specific gravity was used to identify healthy seeds. After that, seeds spent 24 h submerged in water in a pail. From that point onward, seeds were collected from the water then put in gunny bags. The seeds began to grow 48 h in the wake of being splashed, and following 72 h they were planted. At the Bangladesh Agricultural University, a high area of land was chosen for the purpose of cultivating seedlings. A country plough was used to puddle the ground, and a ladder was used to clean and level it. The germination seeds were then planted in the raised nursery beds with continuous furrow irrigation. The seedling nursery was kept clean of weeds throughout the nursery period. The trial land was at first opened up with a farm tractor to set it up. Then the experimental ground was cross-plowed with a country plough to get it ready for ladder leveling. On the land, there were no weeds or brambles. The experimental design that was chosen guided the completion of the field layout. Triple super phosphate, muriate of potash, gypsum, and zinc fertilizer was used to improve the soil at 90-75-60-8 kg/ha, respectively. All of them were applied during the final land preparation. While nitrogen was applied as per treatments in the form of urea at 15, 30, and 45 DAT in equal instalments. Seedlings that were 32 days old were taken out and planted at two seedlings hill^{-1} each in the well puddle plots. The field was irrigated by the flood irrigation method, and steps were taken to maintain a constant level of standing water up to 7 to 10 cm in the field almost throughout the growing season. The field was, however, drained out during the tillering stage to enhance tillering and at the hard dough stage of the grains to facilitate maturity.

Data collection on growth attributes

Plant height, tillers per hill, LAI, and TDM per hill all had recorded at 25, 40, 55, and 70 DAT. Bamboo sticks were used to designate five hills, but not the border rows, in order to keep track of plant height and tiller counts. Every time LAI and TDM sampling dates were applied, five hills were destroyed. Leaf samples from the plot were gathered in order to calculate the LAI (*Eq. 1*). Finally, LAI was deliberate using the following formula after the leaf area was measured by a leaf area meter (Li-Cor 3100 area meter, Li-Cor, Lincoln, NE, USA) (Raford, 1967; Hunt, 1978).

$$LAI = \frac{LA}{P} \quad \text{(Eq.1)}$$

Where LA = Leaf Area and P = Ground Area.

From each plot five plants were harvested every 15 days, up to 85 DAT, to gather samples. The study samples were cleaned, the roots were cut from the culms, and the leaves were freed. The collected plants were heated in oven at temperature 70°C for 72 h until constant weight. The weight of each sample was determined after drying.

Sampling, harvesting, processing and grain protein analysis

Excluding boundary hills, five hills were haphazardly chosen and uprooted in order to collect plant characteristics and yield constituents data. As soon as the plot matured, a sample was taken before the entire plot was harvested. Each plot’s crop was carried to the threshing floor in individual containers with well marked labels. After threshing the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

grains were cleaned, dried, and precisely assessed. Yield of grains (t ha^{-1}) estimate was made using the dry weight of the grains on each plot (*Eq. 2*). Using a moisture meter, the amount of moisture in the grain was calculated. The yield might be determined using the following technique after final weight of grains was changed to have moisture of 14%.

$$\text{Dry Weight} = \frac{(\text{Green Weight}) \times (100 - \text{Moisture content }\%)}{(100 - 14)} \qquad \text{(Eq.2)}$$

Straws were converted into t ha^{-1} once they had fully dried. The harvest index was created using the modified grain and straw yields, and calculated as below (*Eq. 3*).

$$\text{HI }(\%) = \frac{(\text{Grain yield})}{(\text{Biological yield})} \times 100 \qquad \text{(Eq.3)}$$

The protein percent was determined using the Micro-Kjeldahl technique (AOAC, 1984).

Statistical analysis

Data were accurately acquired, processed, and formatted for statistical analysis. To determine the relevance of the variation caused by the experimental treatments, a statistical analysis of the information acquired on various plant attributes was performed. ANOVA was used to evaluate the data, and the DMRT method was used to determine differences between treatment means (Gomez and Gomez, 1984).

Results

Impact on growth characteristics

Plant height

The height of the plant was unaffected at 25, 40, 55, and 70 DAT by combination of variety, spacing and nitrogen (*Table 1*). The BRRI dhan66 cultivar produced the tallest plants (126.40 cm), which were 25 cm apart by 15 cm with100 kg N per ha at 70 DAT.

Number of tillers per hill

The relationship between three major agronomic practices had a substantial impact at just 70 DAT on tillers per hill (*Table 1*). At 70 DAT, the largest proportion of tillers per hill (11.00) was found in BRRI dhan66 planting at 25 cm × 15 cm with 100 kg N per hectare, that was statistically equivalent to the same variety and spacing with 80 kg N per hectare, and the lowest tillers (6.33) was exposed with the association of BRRI dhan62 when plant spacing was 20 cm × 10 cm with 0 kg N per hectare that was statistically similar to the same variety and plant spacing with 60 kg and 0 kg N per hectare (*Table 1*).

Leaf area index

The LAI did not appear to be significantly exaggerated by the interactions of variety, spacing, and nitrogen (*Table 2*). BRRI dhan66 with planting at 25 cm × 15 cm with

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

100 kg N per hectare produced the maximum leaf area index (1.16) whereas BRRI dhan62, plant spacing of 20 cm × 10 cm, and control treatment produced the lowest LAI (0.488) (*Table 2*).

Table 1. *Interaction effect of variety, planting spacing and nitrogen fertilization on plant height and tillers per hill at different days after transplanting*

Interaction (variety × spacing × N level)	Plant height (cm)				No. of tillers $hill^{-1}$			
	Days after transplanting (DAT)				Days after transplanting (DAT)			
	25	40	55	70	25	40	55	70
$V_1 \times D_1 \times N_0$	46.8±4.95	68.67±4.89	92.4±10.61	102.24±0.89	6.8±1.22	7.4±0.31	7.6±0.72	7.53±1.24 hi
$V_1 \times D_1 \times N_1$	46.8±7.03	70±4.35	93.67±4.35	104.33±14.04	6.07±0.27	8.13±0.39	7.8±0.53	7.6±1.01 gh
$V_1 \times D_1 \times N_2$	46.93±7.92	71.8±13.24	95.6±19.36	106.07±8.07	6.47±0.15	8.33±0.59	7.8±1.34	7.73±1.49 gh
$V_1 \times D_1 \times N_3$	47.47±4.94	72±6.73	99.33±20.32	107.8±15.09	7.07±1.43	8.6±0.28	8.27±0.82	8.27±0.71 f
$V_1 \times D_2 \times N_0$	44.8±4.19	68.67±0.09	91.6±11.06	102.07±1.75	5.67±0.32	7±0.58	6.67±0.33	6.6±0.57 klm
$V_1 \times D_2 \times N_1$	46.2±4	69.87±11.79	93±14.39	103.73±10.11	5.93±1	7±1.13	6.73±0.08	6.73±0.56 jkl
$V_1 \times D_2 \times N_2$	46.47±7.32	70.2±3.21	95.2±9.66	104.13±7.89	6±0.47	7.33±1.51	7.13±1.03	6.93±0.88 j
$V_1 \times D_2 \times N_3$	47.47±9.61	71±9.53	95.73±17.25	106.6±5.36	6.53±0.25	8.53±0.07	8.27±0.61	8.17±0.65 f
$V_1 \times D_3 \times N_0$	44.07±8.31	68.33±8.82	89.07±10.13	101.67±6.53	5.33±0.51	6.6±0.38	6.67±0.33	6.33±0.72 m
$V_1 \times D_3 \times N_1$	45.8±3.71	69.2±6.86	93.13±18.52	102.47±8.11	5.8±0.42	6.87±0.64	6.73±0.12	6.47±0.92 lm
$V_1 \times D_3 \times N_2$	46.47±3.63	69.27±3.33	94.47±19.38	102.73±16.7	5.87±0.76	7.13±1.32	7.07±1.2	6.87±0.14 jk
$V_1 \times D_3 \times N_3$	46.8±3.01	70.47±0.35	94.93±18.12	106.6±14.61	6.2±0.8	7.53±1.51	7.4±0.96	7.27±0.47 i
$V_2 \times D_1 \times N_0$	51.67±10.64	80.6±10.94	112.73±13.15	117.6±0.23	7.8±1.13	10.53±0.77	9.67±0.52	9.4±1.6 c
$V_2 \times D_1 \times N_1$	51.93±8.1	84.27±0.57	116.07±2.8	122.87±22.51	7.87±0.94	10.73±2.09	10.4±1.29	9.6±1.81 c
$V_2 \times D_1 \times N_2$	52.67±0.33	84.73±12.96	116.87±23.24	124.47±7.36	7.93±1	11.2±1.04	10.93±1.16	10.8±1.89 a
$V_2 \times D_1 \times N_3$	54.93±9.05	86.6±3.72	117.87±18.49	126.4±4.66	8.4±0.06	11.47±1.75	11±2.26	11±1.63 a
$V_2 \times D_2 \times N_0$	50±0.08	77.47±8.68	107.73±18.95	116.4±13.93	7.07±1.13	8.47±1.59	8.07±0.66	7.87±1.39 g
$V_2 \times D_2 \times N_1$	50.8±5.62	81.33±11.42	114.47±16.03	122.13±4.5	7.13±1.05	9.13±1.53	8.67±1.35	8.6±0.67 de
$V_2 \times D_2 \times N_2$	52.6±7.93	84.33±1.92	116.47±0.94	123.47±16.46	7.93±1.43	10±0.82	9.67±0.89	9.53±0.18 c
$V_2 \times D_2 \times N_3$	54.4±9.44	85.87±11.56	117.53±8.17	124.87±12.69	8.2±1	10.15±0.67	10.07±1.84	10.07±1.1 b
$V_2 \times D_3 \times N_0$	49.8±3.5	75.07±4.35	104.53±19	113.53±8.58	5.87±0.34	8.27±0.13	8±0.15	7.66±0.67 gh
$V_2 \times D_3 \times N_1$	50.67±6.64	79.4±3.52	113.73±11.07	120.87±10.79	7.07±1.16	9.13±0.03	8.27±0.85	8.33±0.27 ef
$V_2 \times D_3 \times N_2$	52.47±7.36	83.07±5.6	114.2±12.02	123.47±25.73	7.4±0.72	9.33±1.78	8.93±0.75	8.86±0.29 d
$V_2 \times D_3 \times N_3$	53.2±8.5	85±13.29	116.4±5.81	124.53±25.87	7.6±0.71	10±0.04	9.5±1.28	9.37±1.61 c
$S\bar{x}$	0.583	1.29	1.25	1.50	0.242	0.195	0.195	0.105
Level of sig.	NS	NS	NS	NS	NS	NS	NS	*
CV (%)	2.06	2.93	2.08	2.30	6.12	3.89	3.30	2.21

Different letters in the same column indicated significant differences at 5% level of probability; ** 1% level of significance. (NS = Not significant; V_1 = BRRI dhan62; V_2 = BRRI dhan66; D_1 = 25 cm × 15 cm; D_2 = 20 cm × 15 cm; D_3 = 20 cm × 10 cm; N_0 = 0 kg N ha^{-1}; N_1 = 60 kg N ha^{-1}; N_2 = 80 kg N ha^{-1}; N_3 = 100 kg N ha^{-1})

Dry matter production

The combination of variety, plant spacing, and nitrogen level had a sizable influence on TDM at 40 and 55 day after transplanting (*Table 2*). At 40 day after transplanting, BRRI dhan66 interaction with distance of 25 cm × 15 cm and 100 kg N per hectare generated the maximum TDM (16.46 g/hill), whereas BRRI dhan62 interaction with spacing of 20 cm × 10 cm and control application of 0 kg N per hectare produced the lowest TDM (10.31 g/hill). At 55 DAT, the connection of BRRI dhan66, plant spacing 25 cm × 15 cm, and use of 100 kg N per hectare showed the highest TDM (21.11 g/hill) and the least TDM (11.45 g/hill) were seen with the combination of BRRI dhan62, 20 cm × 10 cm spacing, and control use of nitrogen which was measurably comparable to the communication of a similar assortment and treatment with planting at 20 cm × 15 cm (*Table 2*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

***Table 2.** Interaction effect of variety, planting spacing and nitrogen fertilization on the production of dry matter and the leaf area index at different days after transplanting*

Interaction (variety × spacing × N level)	Leaf area index	Dry matter production (g hill-1)			
		Days after transplanting (DAT)			
		25	40	55	70
$V_1 \times D_1 \times N_0$	0.65±0.07	7.32±0.52	11.77±0.1 hi	12.43±2.23 kl	14.54±1.67
$V_1 \times D_1 \times N_1$	0.74±0.11	8.15±0.51	11.93±1.61 hi	14.52±0.63 hi	17.59±0.82
$V_1 \times D_1 \times N_2$	0.91±0.15	9.28±1.71	13.55±1.03 fg	15.68±0.37 fg	17.97±3.64
$V_1 \times D_1 \times N_3$	1.1±0.11	10.05±0.94	13.74±1.92 fg	18.02±3.64 c	19.68±4.03
$V_1 \times D_2 \times N_0$	0.61±0.06	6.91±0.01	11.24±0.19 i	12.08±0.67 lm	14.42±1.74
$V_1 \times D_2 \times N_1$	0.67±0.06	8.14±1.37	11.88±1.16 hi	14±2.35 ij	14.72±2.28
$V_1 \times D_2 \times N_2$	0.87±0.14	8.72±0.4	12.13±0.92 h	18.08±1.4 c	16.65±1.69
$V_1 \times D_2 \times N_3$	1.07±0.22	9.58±1.29	13.53±0.68 fg	16.89±0.64 de	19.24±3.47
$V_1 \times D_3 \times N_0$	0.49±0.09	6.39±0.82	10.31±0.66 j	11.45±1.1 m	14.23±1.62
$V_1 \times D_3 \times N_1$	0.66±0.05	7.83±0.78	11.32±0.9 i	13.23±0.95 jk	14.83±2.95
$V_1 \times D_3 \times N_2$	0.85±0.07	8.21±0.39	11.87±1.93 hi	13.31±1.72 jk	15.13±3.1
$V_1 \times D_3 \times N_3$	1.07±0.07	8.86±0.04	13.12±1.8 g	14.54±1.87 hi	18.57±3.54
$V_2 \times D_1 \times N_0$	0.81±0.17	7.85±1.07	13.85±0.03 ef	16.19±2.35 ef	16.82±1.96
$V_2 \times D_1 \times N_1$	0.91±0.14	8.84±0.06	14.52±2.66 cde	16.91±2.02 de	20.04±0.48
$V_2 \times D_1 \times N_2$	1.11±0.01	10.02±1.53	14.8±0.88 bcd	17.43±2.2 cd	20.63±4.1
$V_2 \times D_1 \times N_3$	1.16±0.19	11.14±0.48	16.46±0.61 a	21.11±0.16 a	21.89±3.43
$V_2 \times D_2 \times N_0$	0.78±0	7.74±0.87	12.06±1.44 h	14.5±2.32 hi	16.12±2.83
$V_2 \times D_2 \times N_1$	0.84±0.09	8.58±1.2	13.05±0.48 g	16.74±2.47 de	18.76±2.63
$V_2 \times D_2 \times N_2$	1±0.15	9.89±0.22	14.23±1.9 def	17.07±3.08 de	20.28±0.16
$V_2 \times D_2 \times N_3$	1.13±0.2	10.68±1.44	15.42±1.57 b	19.84±2.42 b	21.57±1.5
$V_2 \times D_3 \times N_0$	0.68±0.05	7.62±0.44	11.92±0.9 hi	14.1±0.82 ij	15.72±2.86
$V_2 \times D_3 \times N_1$	0.82±0.11	8.45±0.37	12.36±1.1 h	16.28±2.67 ef	18.4±1.79
$V_2 \times D_3 \times N_2$	0.99±0.14	9.67±0.65	13.58±2.83 g	15.26±1.48 gh	18.83±1.98
$V_2 \times D_3 \times N_3$	1.12±0.18	10.18±1.59	14.99±3.11 bc	18.04±1.7 c	20.56±1.03
$S\bar{x}$	0.018	0.200	0.224	0.305	0.311
Level of sig.	NS	NS	**	**	NS
CV (%)	3.41	3.95	2.97	3.35	3.03

Different letters in the same column indicated significant differences at 5% level of probability; ** 1% level of significance. (NS = Not significant; V_1 = BRRI dhan62; V_2 = BRRI dhan66; D_1 = 25 cm × 15 cm; D_2 = 20 cm × 15 cm; D_3 = 20 cm × 10 cm; N_0 = 0 kg N ha^{-1}; N_1 = 60 kg N ha^{-1}; N_2 = 80 kg N ha^{-1}; N_3 = 100 kg N ha^{-1})

Impact on yield characteristics and yield

Number of effective tillers per hill

BRRI dhan66 recorded the highest result (6.22) and lowest number (5.50) was in BRRI dhan62 (*Table 3*). Planting spacing influenced effective tillers per hill and the highest result (6.13) was recorded in 25 cm × 15 cm followed by distance of 20 cm × 15 cm (5.83) and the lowest outcome (5.63) was found in 20 cm × 10 cm (*Table 3*). The productive tillers/hill was greatly affected by various nitrogen levels. The 100 kg N per hectare treatment had the highest outcome (6.17), followed by 80 kg N per hectare (5.95), and the control treatment recorded the lowest result (5.56) (*Table 3*). Variable nitrogen levels, spacing, and rice type all had an interaction effect on the quantity of productive tillers/hill, which was measurably critical. The greatest number of effective tillers/hill (7.33) was obtained in BRRI dhan66 and wider distance 25 cm × 15 cm fertilized with 100 kg N per hectare which in terms of statistics, was the same as the combination of same variety and nitrogen treatment with planting distance of 20 cm × 15 cm and the lowest productive tillers/hill (4.67) was noted in association with of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

BRRI dhan62, plant spacing 20 cm × 10 cm with 0 kg N per hectare that was comparable to same variety, distance and 60 kg N/ha and along with being identical to the combination of same variety and 0 kg N per hectare at 25 cm × 15 cm distance (*Table 4*).

Panicle length

The variations have a considerable impact on panicle length. BRRI dhan66 produced the longer panicle (22.22 cm) in contrast to BRRI dhan62 (21.41 cm) (*Table 3*). On panicle length, plant spacing had no discernible impact. The shorter panicle (21.52 cm) was discovered in 20 cm × 10 cm spacing, whereas the longer panicle length (22.09 cm) was discovered in 25 cm × 15 cm spacing (*Table 3*). Significant influences were found on panicle length by nitrogen level. The longest length of panicle (22.43 cm) was noted in 100 kg N/ha which was appropriate for the treatment of 80 kg N/ha and the shortest one (21.28 cm) was found in control treatment that was at par with 60 kg N/ha and 80 kg N/ha (*Table 3*). With regards to the number, the longest panicle (23.74 cm) was recorded in BRRI dhan66, density 25 cm × 15 cm when cultivated using fertilizer at 100 kg N/ha on the contrary the shortest result (20.65 cm) was formed in BRRI dhan62, 20 cm × 10 cm distance with control treatment (*Table 4*).

Number of grains per panicle

Comparing BRRI dhan62 with BRRI dhan66, (*Table 3*) showed that BRRI dhan66 generated more grains/panicle (117.78) than BRRI dhan62 (105.25) showed that variety had a big impact on how many grains were in panicle. Plant spacing had no appreciable impact on grains/panicle. According to the data in (*Table 3*), the distance of 25 cm × 15 cm generated the uppermost grains/panicle (114.8) and 20 cm × 10 cm resulted the least grains/panicle (109.4). The grains/panicle was greatly increased by the nitrogen fertilization. Grans/panicle was significantly affected by nitrogen level. Application of 100 kg N per hectare produced the maximum grains/panicle (115.9), followed 80 kg N per hectare (113.4) while 0 kg N per hectare found the least grains/panicle (107.1) (*Table 3*). The BRRI dhan66, fertilized with 100 kg N per hectare, produced the most grains panicle (129.3), with a spacing of 25 cm × 15 cm, whereas the BRRI dhan62, fertilized with 0 kg N per hectare, formed the lowest result (101.0) when planting at 20 cm × 10 cm (*Table 4*).

Number of sterile spikelets per panicle

The least amount of sterile spikelets per panicle (11.19) was produced in BRRI dhan66, while the higher one (12.42) was produced in BRRI dhan62 reported that it has impacted by variety (*Table 3*). Spacing greatly impacted the sterile spikelets production in the panicle. The lowest amount of sterile spikelets per panicle (11.38) was found at 25 cm × 15 cm distance which was statistically the same with 20 cm × 15 cm, while the largest number (12.38) was found at a distance of 20 cm × 10 cm (*Table 3*). Different nitrogen levels had a noticeable impact on the quantity of sterile spikelets in panicle and the highest result (12.50) was found in control treatment (0 kg N/ha), which was statistically similar to 60 kg N per hectare while the lowest outcome (10.78) was found in 100 kg N per hectare (*Table 3*). It has also greatly influenced by variety, plant spacing and nitrogen level interaction. The maximum amount of sterile spikelets per panicle (14.33) was found in BRRI dhan62, spacing 20 cm × 10 cm with control

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

treatment followed by BRRI dhan62, distance of 20 cm × 10 cm with 60 kg N per hectare (14.00) and the minimum amount (10.0) was obtained in BRRI dhan66, distance of 20 cm ×15 cm with 100 kg N per hectare (*Table 4*).

Weight of 1000-grain (g)

The highest 1000-grain weight (24.74 g) was obtained in BRRI dhan66 and the lowest outcome (23.57 g) was noted in BRRI dhan62 mentioned that it has significant impact on variety (*Table 3*). The maximum 1000-grain's weight (24.75 g) was recorded in the wider distance of 25 cm × 15 cm which was compared by 20 cm × 15 cm (24.22 g) and the least result (23.50 g) was observed in the closer distance of 20 cm × 10 cm (*Table 3*). Various levels of nitrogen had a big impact on the 1000-grain's weight. The heavier 1000-grain's weight (25.02 g) was obtained in 100 kg N per hectare followed by 80 kg N per hectare (24.41 g) and 60 kg N per hectare (24.13 g) and lighter 1000-grain (23.07 g) was documented in 0 kg N per hectare (*Table 3*). The1000-grain weight was not affected by the combination of different types of plants, how close they were planted together, and the amount of nitrogen. The collaboration of BRRI dhan62, spacing 20 cm × 10 cm, with control treatment (0 kg N/ha) produced the lowest weight of 1000 grains expressed numerically (20.40 g), while the maximum one (26.50 g) was found in BRRI dhan66 with 25 cm × 15 cm distance when fertilized with 100 kg N per hectare (*Table 4*).

Table 3. *Impact of variety, plants pacing and nitrogen level on crop parameters, yield attributes and yield of transplanted Aman rice*

Treatment	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Harvest index (%)	Protein content (%)
Variety							
BRRI dhan62	5.5±0.58 b	21.41±1.53 b	105.25±12.09 b	12.42±0.11 a	23.57±4.23 b	43.7±1.81 b	6.33±0.6 b
BRRI dhan66	6.22±0.93 a	22.22±1.38 a	117.78±5.47 a	11.19±1.51 b	24.74±1.08 a	45.58±2.2 a	7.97±0.54 a
Sx̄	5.5±0.58 b	21.41±1.53 b	105.25±12.09 b	12.42±0.11 a	23.57±4.23 b	43.7±1.81 b	6.33±0.6 b
Level of sig.	**	**	**	**	**	**	**
CV (%)	2.80	4.05	1.40	5.14	3.37	2.20	3.34
Spacing (cm)							
25 cm ×15 cm	6.13±1.03 a	22.09±4.07	114.8±23.25 a	11.38±0.87 b	24.75±0.58 a	44.31±3.12	7.8±1.34 a
20 cm × 15 cm	5.83±0.61 b	21.82±2.04	110.4±22.58 b	11.67±1.63 b	24.22±4.89 b	44.7±1.44	7.18±0.71 b
20 cm ×10 cm	5.63±0.53 c	21.52±0.03	109.4±13.21 c	12.38±0.21 a	23.5±1.31 c	44.92±3.69	6.47±0.32 c
Sx̄	0.034	0.180	0.318	0.124	0.166	0.200	0.049
Level of sig.	**	NS	**	**	**	NS	**
CV (%)	2.80	4.05	1.40	5.14	3.37	2.20	3.34
N level (kg ha^{-1})							
0	5.56±0.48 d	21.28±3.59 b	107.1±16.57 d	12.5±1.22 a	23.07±3.87 c	43.54±7.03 b	6.3±0.07 d
60	5.78±0.91 c	21.66±0.99 b	109.6±11.12 c	12.22±0.93 a	24.13±1.87 b	45.47±9.35 a	6.69±0.96 c
80	5.95±1.2 b	21.89±2.94 b	113.4±20.43 b	11.72±0.59 b	24.41±0.92 b	45.47±0.38 a	7.08±0.52 b
100	6.17±1.16 a	22.43±2.89 a	115.9±13.18 a	10.78±0.69 c	25.02±2.4 a	44.1±2.55 b	8.53±0.43 a
Sx̄	0.039	0.208	0.367	0.143	0.192	0.231	0.056
Level of sig.	**	**	**	**	**	**	**
CV (%)	2.80	4.05	1.40	5.14	3.37	2.20	3.34

Different letters in the same column indicated significant differences at 5 % level of probability; ** 1% level of significance. (NS = Not significant; V_1 = BRRI dhan62; V_2 = BRRI dhan66; D_1 = 25 cm × 15 cm; D_2 = 20 cm × 15 cm; D_3 = 20 cm × 10 cm; N_0 = 0 kg N ha^{-1}; N_1 = 60 kg N ha^{-1}; N_2 = 80 kg N ha^{-1}; N_3 = 100 kg N ha^{-1})

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

Table 4. *Interaction effect of variety, plant spacing and nitrogen fertilization on crop parameters, yield attributes and yield of transplanted Aman rice*

Interaction (variety × spacing × N level)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	1000-grain weight (g)	Harvest index (%)	Protein content (%)
$V_1 \times D_1 \times N_0$	5.67±0.6	21.18±1.51	105±12.06 jkl	12.67±0.11	23.4±4.2	43.45±1.8 hij	5.95±0.57 i
$V_1 \times D_1 \times N_1$	5.67±0.85	21.48±1.33	105.3±4.89 jk	12.33±1.66	24.26±1.06	44.02±2.13 g-j	6.31±0.43 hi
$V_1 \times D_1 \times N_2$	5.67±0.96	21.7±4	107.7±21.81 ij	12±0.91	24.3±0.57	46.5±3.28 a-d	6.66±1.15 gh
$V_1 \times D_1 \times N_3$	5.67±0.59	22.23±2.08	113.3±23.17 fg	11±1.54	25±5.05	43.77±1.41 g-j	6.96±0.69 fg
$V_1 \times D_2 \times N_0$	5±0.47	20.92±0.03	102.3±12.36 lmn	12.67±0.22	23±1.28	42.42±3.49 j	5.95±0.29 i
$V_1 \times D_2 \times N_1$	5.67±0.49	21.46±3.62	103.7±16.04 k-n	12.33±1.2	23.5±3.94	44.65±7.21 e-i	6.31±0.07 hi
$V_1 \times D_2 \times N_2$	5.67±0.89	21.58±0.99	105.3±10.68 jk	12±0.91	24.2±1.88	43.87±9.02 g-j	6.31±0.91 hi
$V_1 \times D_2 \times N_3$	5.67±1.15	21.83±2.93	107±19.28 0ij	11.33±0.57	24.66±0.93	43±0.36 ij	7.32±0.54 ef
$V_1 \times D_3 \times N_0$	4.67±0.88	20.65±2.66	101±11.49 n	14.33±0.92	20.4±1.96	39.94±2.31 k	5.3±0.26 j
$V_1 \times D_3 \times N_1$	5.33±0.43	20.94±2.08	102±20.28 mn	14±1.11	23.22±1.67	44.19±4.11 g-j	5.95±0.11 i
$V_1 \times D_3 \times N_2$	5.67±0.44	21.34±1.03	104±21.33 klm	12.67±2.06	23.4±3.03	44.88±8.3 e-i	5.95±1.01 i
$V_1 \times D_3 \times N_3$	5.67±0.36	21.56±0.11	106.3±20.29 jk	11.67±1.6	23.45±3.01	43.77±8.77 g-j	6.96±0.9 fg
$V_2 \times D_1 \times N_0$	6.33±1.3	21.86±2.97	112.7±13.15 fg	11.33±0.02	24.5±3.55	44.16±3.21 g-j	7.62±0.41 de
$V_2 \times D_1 \times N_1$	6.33±0.99	22.13±0.15	117±2.83 cde	11.33±2.08	25±2.98	45.96±8.97 a-f	7.97±0.99 d
$V_2 \times D_1 \times N_2$	6.33±0.04	22.42±3.43	128±25.45 a	10.67±0.63	25±3.16	43.3±4 hij	8.63±0.91 c
$V_2 \times D_1 \times N_3$	7.33±1.21	23.74±1.02	129.3±20.28 a	9.67±0.36	26.5±0.2	43.31±6.6 hij	12.32±2.53 a
$V_2 \times D_2 \times N_0$	6±0.01	21.7±2.43	111.7±19.64 gh	12±1.44	23.6±3.77	44.55±8.36 e-i	6.66±0.55 gh
$V_2 \times D_2 \times N_1$	6±0.66	22±3.09	115.3±16.15 def	11.67±0.43	24.5±3.61	46.26±7.74 a-e	6.96±1.08 fg
$V_2 \times D_2 \times N_2$	6.33±0.95	22.18±0.5	117.3±0.95 cd	11.33±1.51	25±4.51	47.16±3.88 ab	7.62±0.7 de
$V_2 \times D_2 \times N_3$	6.33±1.1	22.91±3.08	120.3±8.37 b	10±1.02	25.3±3.09	45.66±3 b-g	10.29±1.88 b
$V_2 \times D_3 \times N_0$	5.67±0.4	21.34±1.24	109.7±19.93 hi	12±0.91	23.5±1.36	46.73±0.75 abc	6.31±0.12 hi
$V_2 \times D_3 \times N_1$	5.67±0.74	21.93±0.97	114.3±11.13 efg	11.67±1.04	24.3±3.99	47.72±0.13 a	6.66±0.69 gh
$V_2 \times D_3 \times N_2$	6±0.84	22.12±1.49	118.3±12.46 bc	11.67±2.43	24.53±2.37	47.07±8.97 ab	7.32±0.62 ef
$V_2 \times D_3 \times N_3$	6.33±1.01	22.29±3.49	119.3±5.96 bc	11±2.28	25.2±2.37	45.07±0.19 c-h	7.32±0.98 ef
$S\bar{x}$	0.095	0.510	0.900	0.351	0.469	0.566	0.138
Level of sig.	**	NS	**	NS	NS	**	**
CV (%)	2.80	4.05	1.40	5.14	3.37	2.20	3.34

Different letters in the same column indicated significant differences at 5% level of probability; ** 1% level of significance. (NS = Not significant; V_1 = BRRI dhan62; V_2 = BRRI dhan66; D_1 = 25 cm × 15 cm; D_2 = 20 cm × 15 cm; D_3 = 20 cm × 10 cm; N_0 = 0 kg N ha^{-1}; N_1 = 60 kg N ha^{-1}; N_2 = 80 kg N ha^{-1}; N_3 = 100 kg N ha^{-1})

Grain yield

Variety influenced significantly and BRRI dhan66 produced the more grain (4.07 t/ha) compared to BRRI dhan62 (3.06 t/ha) (*Fig. 2*). Density played a big role in how much grain was produced. When the plants were spaced further apart, they produced more grains. On the other hand, when the plants were spaced closer together, they produced fewer grains. Planting spacing 20 cm × 15 cm produced the maximum grain output (3.79 t/ha), followed by distance of 25 cm × 15 cm (3.52 t/ha), while spacing 20 cm × 10 cm produced the lowest grain (3.38 t/ha) (*Fig. 2*). The amount of nitrogen in the soil affected how much rice was grown. The 100 kg N per hectare treatment provided the top most quantity of grain (3.939 t ha-1), followed by the 80 kg N/ha treatment (3.71 t/ha), while the control nitrogen (0 kg N/ha) produced the minimum yield of grain (3.12 t/ha) (*Fig. 2*). The amount of grain that plants produced

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

was greatly influenced by the combination of different types of plants, how close together they were planted, and the level of nitrogen that was provided. The combination of BRRI dhan66 with planting distance of 25 cm × 15 cm with fertilization of 100 kg N per hectare recorded the utmost yield of grain (4.52 t/ha), that was numerically similar to the same variety with the same spacing with fertilization of 80 kg N per hectare and also identical to the same variety with planting distance of 20 cm × 15 cm with 100 kg N per hectare (*Fig. 2*).

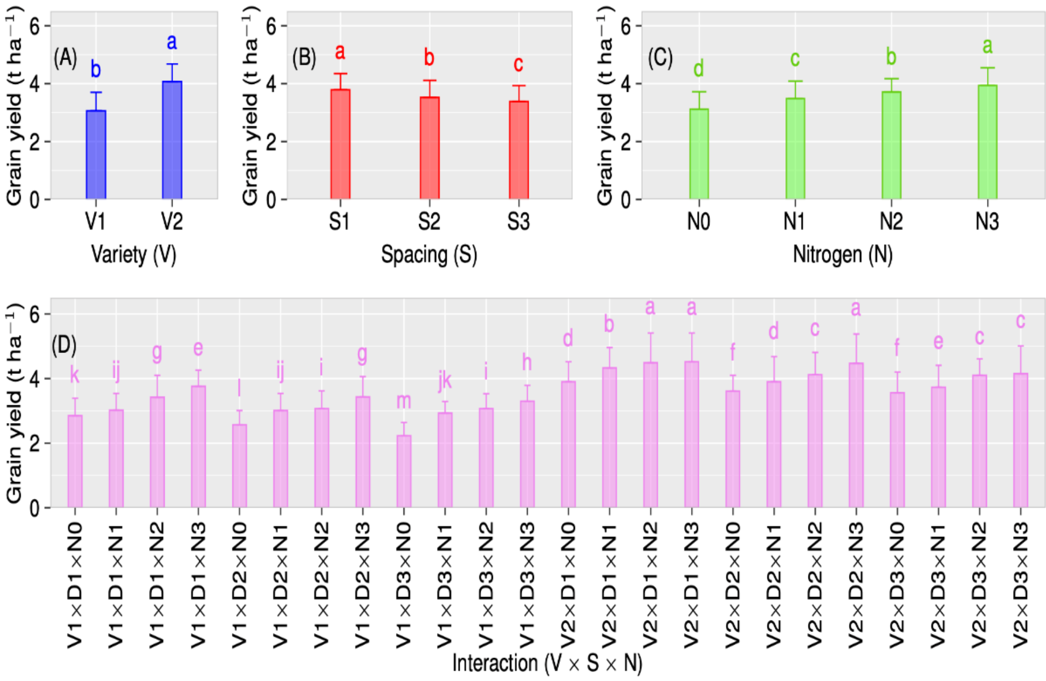

Figure 2. *Impact of variety, spacing, nitrogen and their interactions on grain yield*

Straw yield

The different types of plants had a big impact on how much straw was produced. It was recorded that the higher yield of straw (4.88 ton per ha) was in BRRI dhan66 the lower was (3.92 t/ha) in BRRI dhan62 (*Fig. 3*). The distance between plants had a big impact on how much straw was produced. The plant spacing that produced the maximum quantity of straw (4.77 ton per ha) was 25 cm × 15 cm which was compared by 20 cm × 15 cm (4.33 ton per ha) while the lowermost amount of straw (4.11 ton per ha) from 20 cm × 10 cm plant distance (*Fig. 3*). The amount of nitrogen has a major impact on straw production and the largest quantity (4.99 ton per ha) was produced with 100 kg of nitrogen per hectare, followed by 80 kg N per hectare (4.45 ton per ha) and the lowest production of straw (4.01 ton per ha) with the control treatment (*Fig. 3*). The combination of different types of plants, how far apart they are planted, and the amount of nitrogen used had a big influence on the yield of straw. The most elevated the yield of straw (5.92 ton per ha) was kept in the BRRI dhan66 at separating 25 cm × 15 cm with utilization of 100 kg N per hectare, which was comparable concerning measurements to a similar assortment and dispersing with use of 80 kg N per hectare while the least yield of straw (3.35 ton per ha) was kept in the BRRI dhan62 at dividing 20 cm × 10 cm with control treatment (*Fig. 3*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

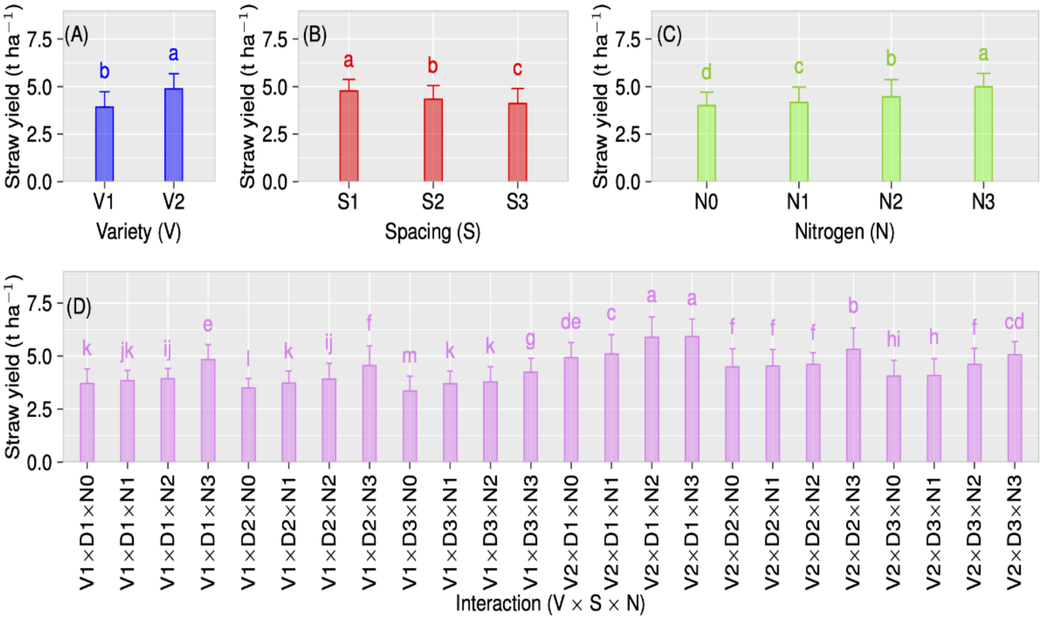

***Figure 3.** Impact of variety, spacing, nitrogen and their interactions on straw yield*

Harvest index (HI)

Table 3 showed that the higher HI (45.58%) was calculated in BRRI dhan66 compared to BRRI dhan62 (43.7%) that confirmed significant impact of verity on HI. Planting density had substantial effect on harvest index. The planting method with the greatest harvest index (44.92%) was distance of 20 cm × 10 cm followed by 20 cm × 15 cm spacing (44.70%), while the planting method with the despicable HI (44.31%) was 25 cm × 15 cm distance (*Table 3*). The range of HI was found from 43.54% to 45.47% influenced significantly by nitrogen level. The fertilization rate of 80 kg N per ha, that was comparable to 60 kg N per ha, produced the greatest HI (45.47%). The application of control fertilizer resulted in the lowest harvest index (43.54%) which was statistically on par with the highest N dose (*Table 3*). The HI was important in how different varieties of plants, the spacing between them, and the amount of nitrogen affected each other. The best harvest index results (47.72%) were recorded when BRRI dhan66 was planted with a spacing of 20 cm × 10 cm and given 60 kg N per ha. This outcome was comparable to that obtained when planting the same rice variety with the same spacing but giving it 80 kg N per ha, as well as to that found when planting it with a distance of 20 cm × 15 cm and giving it 80 kg N per ha. The BRRI dhan62 produced the lowest yield (39. 94%) when it was planted with a 20 cm × 10 cm spacing and 0 kg N per ha (*Table 4*).

Effect on qualitative character

Grain protein content

Protein content in grains changed greatly as a result of variety which ranged from 6.33 to 7.97%. The higher protein content of grain (7.97%) was found in BRRI dhan66 and the lower result (6.33%) was recorded in BRRI dhan62 (*Table 3*). The highest protein content of grain (7.80%) was found in spacing 25 cm × 15 cm followed by

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2202_10131028

20 cm × 15 cm spacing (7.18%) which had showed significant impact of plant spacing and the lowest outcome (6.47%) was found by planting 20 cm × 10 cm spacing (*Table 3*). The quantity of nitrogen has a substantial impact on the protein content of grains (*Table 3*). From 6.30% to 8.53% of grains were found to have protein. The 100 kg N/ha fertilization had the greatest protein content of grain (8.53%), followed by the 80 kg N/ha fertilized area (7.08%), and the control treatment had the lowest (6.30%). Grain protein content showed a sizable effect on above mentioned three major agronomic practices. The highest protein content of grain (12.32%) was found in the BRRI dhan66, density 25 cm × 15 cm with fertilization of 100 kg N/ha; this was followed by the BRRI dhan66, 20 cm × 15 cm with application of 100 kg N/ha (10.29%); and the lowest outcome (5.30%) was found in the BRRI dhan62, density 20 cm × 10 cm with 0 kg N/ha (*Table 4*).

Discussion

In this recent study, we revealed that the best growth attributes like height of the plant, tillers per hill, LAI and TDM were achieved at 70 DAT using a combination of the BRRI dhan66 variety, distance of 25 cm × 15 cm, and nitrogen 100 kg per ha area that was using a distance of 20 cm × 15 cm with the same variety and fertilizer dose produced statistically similar results. According to (Jahan et al., 2017), the introduction of optimal solar radiation at (25 cm × 15 cm) intervals, which improved photosynthesis, may have contributed to the highest plant height. Plants fight with each other for room, food, water, sunlight, and air when they are grown close together. When plants are tightly packed, there are fewer tillers per square meter. However, when plants are spread out, there is less competition between plants and each plant has more tillers (Mahato and Adhikari, 2017). This observation matched with the LAI and TDM (Roy et al., 2020), who found that spacing the rice plants correctly and giving them the right nutrients allows them to use nutrients and moisture efficiently, as well as get the most sunlight. This results in the rice plants growing faster.

In this study, BRRI dhan66 produced higher grain yield over BRRI dhan62. This is due to the fact that BRRI dhan66 generated the higher productive tillers per hill, length of the panicle and grains per panicle. The differences in the genes of a plant may be the reason for the differences in how much it produces. The result was the same as what (Tyeb et al., 2013; Pal et al., 2016; Sarkar et al., 2016) had discovered. In this study, greater distance (25 cm × 15 cm) produced the greatest results for the maximum effective tillers per hill, length of the panicle, grains per panicle, grain and straw yield, and protein content of grain (%), whereas narrow distance (20 cm × 10 cm) made the poorest outcomes. Wider distance reduced mutual shading and competition (Oad et al., 2001) for nutrients and water intake, allowing the plant density to increase the amount of sunlight the plants received and the amount of biomass they produced (Mohaddesi et al., 2011). There were more characters to add as a result. These components of the highest yield allowed for the best grain yield to be achieved as well.

Rice needs nitrogen to grow healthily and yield a decent crop. In this study, the maximal dose (100 kg N per ha) created the highest outcomes in terms of the quantity of productive tillers per hill, length of the panicle, grains per panicle, and the least quantity of sterile spikelets per panicle. Higher values of these factors result in the highest grain yield, straw yield, and harvest indexes. Additionally, the maximum protein content was reported when fertilization with 100 kg N per ha. However, throughout rice growth and development, agronomic treatments, soil and climate conditions, and genetic background all affect the quality of rice grains. According to earlier findings, raising the N rate increased both cultivars' protein content (Leesawatwong et al., 2005). Using nitrogen properly probably helped cells function better during growth, which caused more parts of the plant to grow, resulting in a higher yield (Ray et al., 2015). The highest effective tillers per hill, length of the panicle, grains per panicle, and the least number of sterile spikelets per panicle were all generated at the greatest levels on interaction with BRRI dhan66, plant spacing of 25 cm × 15 cm, and 100 kg N per ha. All of these factors helped the plants grow more grain and straw. Additionally, the most protein was present in the grain in this combination. The reason why there is a lot of protein is because there is enough nitrogen in the soil that plants can use. After adding nitrogen, the level of protein in rice grains increased a lot (Sarkar et al., 2014; Ray et al., 2015).

Conclusions

In conclusion, maximizing rice yield is of paramount importance for rice-based developing countries as they strive to feed their growing population. Depending on the type of soil and weather patterns, in order to enhance yield and protein percentages of grain, it may be stated that BRRI dhan66 planting at 25 cm × 15 cm distance with 100 kg N per ha seems to be a favorable strategy.

Acknowledgments. Swapan Kumar Paul extends his gratefulness to Ministry of Science and Technology, Bangladesh. The authors also would like to extend their heartfelt gratitude to the Researchers Supporting Project Number (RSP2024R134), King Saud University, Riyadh, Saudi Arabia.

Conflict of interests. The authors certify that they have no financial or other competing interests to disclose with relation to the current work.

Data availability statement. The data presented in this study are available on request from the corresponding author. The data are not publicly available since these data are published for the first time. The authors have no problems providing them on request.

REFERENCES

[1] AOAC (1984): Official Methods of Analysis. – Association of Official Agricultural Chemists (AOAC), Washington, DC.

[2] BBS, Bangladesh Bureau of Statistics (2022): Statistical Year Book of Bangladesh. – Statistics Division, Ministry of planning, Government of People's Republic, Bangladesh. Dhaka. http://www.bbs.gov.bd/site/page/29855dc1-f2b4-4dc0-9073 f692361112da/Statistical-Yearbook.

[3] Chandel, G., Banerjee, S., Meena, S., Sharma, D. J., Verulkar, S. B. (2010): Effect of different nitrogen fertilizer levels and native soil properties on rice grain Fe, Zn and protein contents. – Rice Science 17: 213-227.https://doi.org/10.1016/S1672-6308(09)60020-2.

[4] FAO, Food and Agricultural Organization (2022): World Food and Agriculture – Statistical Yearbook. Food and Agricultural Organization of the United Nations, Rome. https://www.fao.org/documents/card/en/c/cc2211en.

[5] Gomez, K. A., Gomez, A. A. (1984): Statistical Procedures for Agricultural Research, International Rice Research Institute. – John Wiley and Sons, New York.

[6] Hossain, M. S., Monshi, F. I., Kamal, A. M. A., Miah, M. F. (2010): Grain yield and protein content of transplant Aman rice as influenced by variety and rate of nitrogen. – Journal of Agroforestry and Environment 3(2): 235-238.
[7] Hunt, R. (1978): Plant Growth Analysis Studies in Biology. – Edward Arnold Ltd., London, pp. 67-71.
[8] IRRI, International Rice Research Institute (1997): Rice Production Manual. – UPLB, Los Banos.
[9] Islam, A. K. M. M., Sarkar, M. A. R., Islam, N. (2007): Effect of spacing and nutrient management in SRI method on the yield components and yield of transplant Aman rice. – Bangladesh Journal of Crop Science 18: 1-6.
[10] Jahan, S., Sarkar, M. A. R., Paul, S. K. (2017): Variations of growth parameters in transplanted Aman rice (cv. BRRI dhan39) in response to plant spacing and fertilizer management. – Archives of Agriculture and Environmental Science 2(1): 1-5.
[11] Khatun, M. R., Sarkar, M. A. R., Kabiraj, M. S., Sarkar, S. K., Harun, M. H., Paul, S. K. (2023): Influence of nitrogen and phosphorus on the growth and yield of fine aromatic rice (cv. Binadhan13). – Journal of Agroforestry and Environment 16(1): 96-103. https://doi.org/10.55706/jae1612.
[12] Leesawatwong, M., Jamjod, S., Kuo, J., Dell, B., Rerkasem, B. (2005): Nitrogen fertilizer increases seed protein and milling quality of rice. – Cereal Chemistry 82: 588-593. https://doi.org/10.1094/CC-82-0588.
[13] Mahato, M., Adhikari, B. B. (2017): Effect of planting geometry on growth of rice varieties. – International Journal of Applied Sciences and Biotechnology 5(4): 423-429. https://doi.org/10.3126/ijasbt.v5i4.18041.
[14] Maqsood, M., Shehzad, M. A., Ali, S. N. A. Iqbal, M. (2013): Rice cultures and nitrogen rate effects on yield and quality of rice (Oryza sativa L.). – Turkish Journal of Agriculture and Forestry 37: 665-673. https://doi.org/10.3906/tar-1203-5.
[15] Mohaddes, A., Abbasian, A., Bakhshipour, S., Aminpanah, H. (2011): Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high yield rice. – American-Eurasian Journal of Agricultural and Environmental Science 10: 893-900.
[16] Oad, F. C., Solangi, B. K., Samo, M. A., Lakho, A. A., Hassan, Z. U., Oad, N. L. (2001): Growth, yield and relationship of rapeseed under different row spacing. – International Journal of Agriculture and Biology 3: 475-476.
[17] Pal, S., Paul, S. K., Sarkar, M. A. R., Gupta, D. R. (2016): Response on yield and protein content of fine aromatic rice varieties to integrated use of cowdung and inorganic fertilizers. – Journal of Crop and Weed 12(1): 01-06.
[18] Paul, S. K., Roy, B., Hasan, A. K., Sarkar, M. A. R. (2017): Yield and yield performance of short duration transplant Aus rice (cv. Parija) as influenced by plant spacing and nitrogen level. – Journal of Fundamental and Applied Agriculture 2(2): 233-236.
[19] Peng, S., Buresh, R. J., Huang, J. (2010): Improving nitrogen fertilization in rice by site-specific N management. A review. – Agron. Sustain. Dev. 30: 649-656. https://doi.org/10.1051/agro/2010002.
[20] Radford, P. J. (1967): Growth analysis formulae - their use and abuse. – Crop Science 7: 171-175. https://doi.org/10.2135/cropsci1967.0011183X000700030001x.
[21] Ray, S., Sarkar, M. A. R., Paul, S. K., Islam, A. K. M. M., Yeasmin, S. (2015): Variation of growth, yield and protein content of transplant Aman rice by three agronomic practices. – Journal of Agricultural and Biological Sciences 1(4): 167-176.
[22] Roy, P., Sarkar, M. A. R., Paul, N. C., Saha, K. K., Paul, S. K. (2020): Response of integrated fertilizer and weed management on weed occurrence and growth traits of aromatic Boro rice. – Archives of Agriculture and Environmental Science 5(3): 337-346. https://doi.org/10.26832/24566632.2020.0503015.
[23] Sarkar, S. K., Sarkar, M. A. R., Islam, N., Paul, S. K. (2014): Yield and quality of aromatic fine rice as affected by variety and nutrient management. – Journal of

Bangladesh Agricultural University 12(2): 279-284. https://doi.org/10.3329/jbau.v12i2.28683.
[24] Sarkar, S. K., Sarkar, M. A. R., Islam, N., Paul, S. K. (2016): Morpho-physiological attributes of three HYV aromatic fine rice varieties as affected by integrated nutrient management. – Journal of Agroforestry and Environment 10(1): 57-61.
[25] Tayefeh, M., Sadeghi, S. M., Noorhosseini, S. A. (2018): Environmental impact of rice production based on nitrogen fertilizer use. – Environ Sci Pollut Res. 25: 15885-15895. https://doi.org/10.1007/s11356-018-1788-6.
[26] Tyeb, A., Paul, S. K., Samad, M. A. (2013): Performance of variety and spacing on the yield and yield contributing characters of trans-planted Aman rice. – Journal of Agroforestry and Environment 7(1): 57-60.
[27] UNDP, United Nations Development Programme and FAO, Food and Agriculture Organization (1988): Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2. Agro-ecological Regions of Bangladesh. – Bangladesh Agricultural Research Council, Dhaka, pp. 212-221.