*J Bangladesh Agril Univ 21(4): **439-451**, 2023* https://doi.org/10.5455/JBAU.165083

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Integrated Nitrogen Management on Weed Growth and Yield Performance of Transplant *Aman* Rice

Sinthia Afsana Kheya✉, Md. Abdus Salam and Md. Romij Uddin

Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

ARTICLE INFO

Article history
Received: 13 August 2023
Accepted: 13 December 2023
Published: 31 December 2023

Keywords
T. *aman* rice,
Weed density,
Nitrogen,
Nitrogen use efficiency,
Grain yield

Correspondence
Sinthia Afsana Kheya
✉: sinthia.agron@bau.edu.bd

ABSTRACT

Rice requires nitrogen in larger quantities than any other nutrient, and it is the most critical limiting factor that influences grain yield. But inappropriate sources and management of nitrogen is considered to be the most critical one among the various reasons of low rice productivity. In order to address the problem, an experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during June to October 2020 to determine the effect of integrated nitrogen management (INM) on weed growth and yield of transplant *aman* rice. The experiment comprised five *aman* rice varieties, viz. Binadhan-7 (V_1), BRRI dhan56 (V_2), BRRI dhan66 (V_3), BRRI dhan71 (V_4) and BRRI dhan75 (V_5) and four nitrogen management approaches: control (no nitrogen) (N_0), 100% of recommended dose (RD) of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}) (N_1), 2.5 t ha^{-1} poultry manure + 75% of RD of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}) (N_2) and application of USG (1.8 g per 4 hills) (N_3). Results reveal that maximum weed density and dry weight were found in BRRI dhan56 whereas minimum ones were observed in BRRI dhan66. In case of INM, application of 100% of RD of nitrogenous fertilizer as prilled urea showed maximum weed density and dry weight but minimum ones were found with application of USG. In combine, weed density and dry weight were found highest in BRRI dhan56 with 100% of RD of urea and the lowest weed density was found in BRRI dhan66 with no nitrogen treatment at 20 DAT and in BRRI dhan66 with application of USG at 35 DAT and lowest weed dry weight was obtained from Binadhan-7 with application of USG (1.8 g per 4 hills) at 20 and 35 DAT. Variety Binadhan-7 showed superior performance in terms of yield and yield attributes. Application of USG showed the highest number of grains panicle^{-1} and grain yield. Interaction of Binadhan-7 with application of USG produced highest number of grains panicle^{-1} (116.60), highest grain yield (5.21 t ha^{-1}), biological yield (10.94 t ha^{-1}), harvest index (47.65%) and highest BCR (1.57). So, results indicated that Binadhan-7 with application of USG (1.8 g per 4 hills) might be recommended for obtaining highest grain yield with higher nitrogen use efficiency, highest BCR as well as to control weed more effectively in *aman* season.

Introduction

Rice (*Oryza sativa* L.) is the staple food of Bangladesh and it ranks third among the rice producing countries of the world. The suitability of agro-climatic conditions of Bangladesh for growing rice make it possible to cultivate rice year-round. The country is now producing 37.61 million tons of rice in 11.70 million hectares of land to feed her millions of people (BBS, 2021). In Bangladesh, rice is grown in three distinct growing seasons namely, '*aus*' (March to July), '*aman*' (July to December) and '*boro*' (December to May). About 11.15%, 47.93% and 40.91% of total cropped area are occupied by *aus, aman* and *boro* rice, respectively (BBS, 2021). Among these seasons *aman* rice covers the largest area of 5.61 million hectares with the production of 14.44 million metric tons of rice (BBS, 2021). Though being staple food and having favorable agro-climatic condition, its expansion is limited due to shortage of land and to meet the need of increasing population. Therefore, farmers and agricultural scientists are concentrating their focus towards improved technology for increasing rice production. Prodhan (1992) stated that judicial application of fertilizer is an essential component of modern farming with about 50% of the world crop production. To get higher yield of crop and to reduce the cost of fertilizer efficient fertilizer management should be practiced (Hossain and Islam, 2006). Among various nutrients, nitrogen is an essential nutrient that has the strongest influence on the growth and yield of rice. Nitrogen is one of the most yield limiting nutrients in rice production around the world, especially in tropical Asian soils and almost every farmer has to apply

Cite This Article
Kheya, S.A., Salam, M.A. and Uddin, M.R. 2023. Integrated Nitrogen Management on Weed Growth and Yield Performance of Transplant *Aman* Rice. *Journal of Bangladesh Agricultural University,* 21(4): 439-451. https://doi.org/10.5455/JBAU.165083

nitrogen due to get a desirable yield of rice (Saleque et al., 2004). By proper application of nitrogenous fertilizer, it is possible to increase yield by 70 to 80% (IFC, 1982). However, both weed and rice plants compete for nitrogen and in a weed infested field weeds uptake nitrogen more rapidly than rice plant, particularly at high nitrogen levels (Nyarko and De Datta, 1993). Weed is one of the most important pests causing reduction of grain yield by 70-80% in *aus* rice, 30-40% in transplant *aman* rice and 22-36% in *boro* rice (BRRI, 2009). It was found that, growth and seed production of *Echinochloa crus-galli* increased with increase in nitrogen rate resulting lesser nitrogen availability to the rice plants (Chauhan and Abugho, 2013). Therefore, proper nitrogen management is a key factor for evaluating the effect of nitrogen on weed infestation behavior as well as growth and productivity of transplant *aman* rice. But inadequate and improper management of nitrogen are now considered as one of the major reasons of low yield of rice in Bangladesh. So, for obtaining proper benefit from nitrogen management, it is necessary to apply nitrogen properly by maintaining varietal requirement, timing of application, method and dose of application.

It is important to know about proper nitrogen management in correspondence with a variety and agro-climatic conditions of a region. But the farmers do not apply nitrogen in their field timely and properly. On the other hand, the applied nitrogen can be lost due to leaching, surface runoff, ammonia volatilization, de-nitrification and other processes so the nitrogen use efficiency is decreased. Nitrogen use efficiency of rice crop largely ranges between 25-35% and seldom exceeds 50% (Singh et al., 1999). Plant growth is seriously hampered when lower dose of nitrogen is applied, which drastically reduce the crop yield (Adhikari et al., 2018). Excess amount of nitrogenous fertilizer results in lodging of plants, prolonged growing period and ultimately reduces yield (Uddin, 2003). There are several organic and inorganic sources of nitrogen available in the market and in this study prilled urea, urea super granule (USG) and poultry manure were considered as the sources of nitrogen. Generally, prilled urea is applied by broadcasting in splitting manner. Split application of urea fertilizer is efficient because it minimizes the loss of nitrogen. But broadcast application of urea on the surface soil can cause nitrogen loss up to 50% whereas point placement of urea super granule (USG) in 10 cm depth may result in negligible loss (Crasswell and De Datta, 1980). It is proved that chemical fertilizers can supply nutrients for plant growth but can't improve soil quality. In this aspects, addition of organic materials is a trusted weapon for supplying nutrients as well as restoring soil health. On the other hand, in order to achieve higher productivity goal, the soil must be enriched with organic matter. Application of poultry manure can enrich soil with organic matter. Furthermore, integration of poultry manure along with inorganic fertilizers can increase grain yield and protein content of rice (Sarkar et al., 2014). Keeping all these in views, the present research work was conducted to evaluate the effect of integrated nitrogen management on weed dynamics and yield performance of transplant *aman* rice.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during the period from June to October 2020. The experimental site was located at 24°75' N latitude and 90°50' E longitudes at an elevation of 18 m above the mean sea level. The experimental field belongs to the Old Brahmaputra Floodplain (AEZ-9). The region occupies a large area of Brahmaputra sediments which were laid down before the river shifted into its present Jamuna Channel about 200 years ago (UNDP and FAO, 1988). The soil of experimental site belongs to the Sonatola soil series of non-calcareous dark grey flood plain soil under the Old Brahmaputra Alluvial floodplain. The climate of the experimental site is under sub-tropical in nature and is characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during Kharif (April to September) season.

This experiments consisted of two factors: factor A-: five varieties: Binadhan-7 (V_1), BRRI dhan56 (V_2), BRRI dhan66 (V_3), BRRI dhan71 (V_4), and BRRI dhan75 (V_5); factor B: four nitrogen management approaches: control (no nitrogen) (N_0), 100% of recommended dose (RD) of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}) (N_1), 2.5 t ha^{-1} poultry manure + 75% of RD of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}) (N_2) and application of USG (1.8 g per 4 hills) (N_3). The experiment was laid out in a randomized complete block design (RCBD) with three replications.

The field was fertilized as per treatment specification. Nitrogen was applied in the form of urea, USG as a source of inorganic N and poultry manure as a source of organic fertilizer. At the time of final land preparation full dose of triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate were applied at the rate of 80 kg ha^{-1}, 100 kg ha^{-1}, 100 kg ha^{-1} and 10 kg ha^{-1}, respectively in all plots (BRRI, 2020). As per treatment specification urea was applied @ 150 kg ha^{-1} in three equal splits at 10, 25 and 40 DAT. Poultry manure was applied @ 2.5 t ha^{-1} during final land preparation for proper decomposition. In case of USG, after 7 days of transplanting pellets of USG (1.8 g) were placed manually by hand in the root zone at 8 cm depth of the soil at the center of four hills of two adjacent rows. Intercultural operations like weeding (20 and 35 DAT), gap filling (10 DAT), irrigation (2 times) and bund repairing (10 DAT) were done.

Weed density was calculated at 20 DAT and 35 DAT with the help of a quadrate of size 25 cm^2. The quadrate was placed randomly in each plot and the weeds inside the quadrate was counted and then converted to number m^{-2}. After counting the weed density, the weeds inside each quadrate were uprooted and cleaned. To determine dry matter, the sample weeds were first air dried for 6-8 hours. Then the weed samples were packed in labeled brown paper bag and dried in the oven at 80 °C for 72 hours until constant weight was reached. After oven drying, the weed samples were weighed by using electric balance.

The crops were harvested at full maturity (when 90% of the grain became golden yellow in color). The varieties were matured at different dates so that the harvesting dates were different from each other. BRRI dhan56 (117 days) and BRRI dhan75 (117 days) were harvested on 11 October 2020, BRRI dhan66 (130 days) and BRRI dhan71 (130 days) were harvested on 24 October and on 26 October 2020 Binadhan-7 (132 days) was harvested. At harvest data on plant height (cm), number of total and effective tillers $hill^{-1}$, panicle length (cm), number of grains $panicle^{-1}$, number of sterile spikelets $panicle^{-1}$, 1000-grain weight (g), grain yield ($t\ ha^{-1}$) and straw yield ($t\ ha^{-1}$) were collected and biological yield ($t\ ha^{-1}$) and harvest index (%) were calculated using following formulae.

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

$$\text{Harvest index (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

The nitrogen use efficiency (NUE) was calculated based on the grain yield in plots treated with nitrogen and control (no nitrogen) plots. The NUE was expressed as the partial factor productivity (PFP) and agronomic efficiency (AE).

Partial factor productivity (PFP)

It is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied (Fixen et al., 2014).

$$\text{PFP} = \frac{\text{Yield of harvested portion of crop with N applied (kg grain)}}{\text{Amount of applied N(kg)}}$$

Agronomy efficiency (AE_N)

It is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return (Alam et al., 2006; Fixen et al., 2014).

$$AE_N = \frac{\text{Grain yield at applied N dose} - \text{grain yield at no N dose}}{\text{Amount of applied N}} \text{kg kg}^{-1}$$

Data recorded for weed parameters, yield and yield contributing characters were statistically analyzed using “Analysis of Variance” technique with the help of computer program, MSTAT. The significance of mean difference among the treatments was adjudged by Duncan’s Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Correlation coefficient and regression equation was measured by using Microsoft excel program.

The cost of individual head of expenditure was recorded and partial budget analysis was done. The budget consists of the following headings.

Variable cost

All non-material and material costs constituted the variable cost. Eight working hours of a labor and a pair of bullocks were considered as a man-day and an animal day, respectively.

Gross return

Gross return was computed by adding market values of grain and straw yields.

Net income

Net income was calculated by using the following formula:

Net income= gross income - variable cost

Benefit cost ratio (BCR)

Benefit Cost Ratio (BCR) was calculated by using the following formula:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross income}}{\text{Total cost of production}}$$

Results and Discussion

Effect of variety on weed density and dry weight

Weed density and dry weight were significantly influenced by variety at both sampling dates. Maximum weed density (91.33 m^{-2} and 104.00 m^{-2}, respectively) and dry weight (29.50 g m^{-2} and 38.50 g m^{-2}, respectively) at both 20 DAT and 35 DAT were found in

BRRI dhan56. The lowest weed density (70.66 m^{-2} and 83.00 m^{-2}, respectively) and dry weight (19.56 g m^{-2} and 28.93 g m^{-2}, respectively) at both 20 and 35 DATs were recorded in BRRI dhan66 (Figure 1). The lowest weed dry weight of BRRI dhan66 was statistically similar with the lowest weed dry weight (21.40 g m^{-2} and 30.00 g m^{-2} at 20 DAT and 35 DAT, respectively) of Binadhan-7 at all sampling dates. Crop species, even variants of the same species, have different capacities for engaging in resource competition. The cultivars with the lowest weed density were able to suppress the weeds because they were more potent to compete for resources than weeds. Salma et al. (2017) also reported that weed population was significantly influenced by variety. The potentiality of a variety to keep down weeds is shown by lower weed biomass, and the opposite is also true. By measuring weed biomass under weedy circumstances, one can estimate weed suppressive ability of a variety (Zhao et al*.,* 2006).

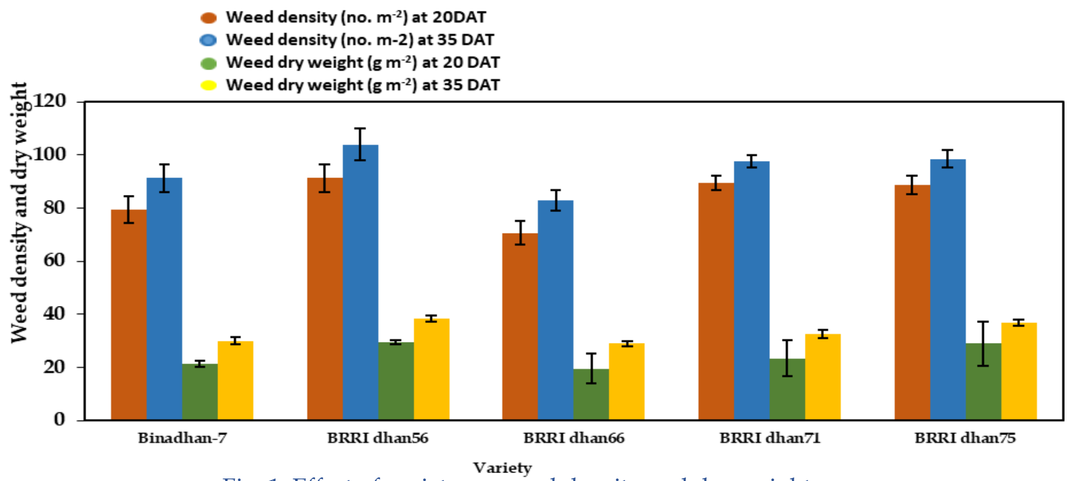

Fig. 1. Effect of variety on weed density and dry weight

Effect of nitrogen management on weed density and dry weight

Nitrogen management had significant effect on weed density and dry weight. Both weed density and dry weight at 20 DAT (98.13 m^{-2} and 28.00 g m^{-2}) and 35 DAT (107.20 m^{-2} and 37.17 g m^{-2}) were found maximum with the application of 100% of RD of prilled urea (150 kg ha^{-1}) (Figure 2). The lowest weed density and dry weight at 20 DAT (72.80 m^{-2} and 22.62 g m^{-2}) and at 35 DAT (83.68 m^{-2}, 30.34 g m^{-2}) was found with the application of USG.

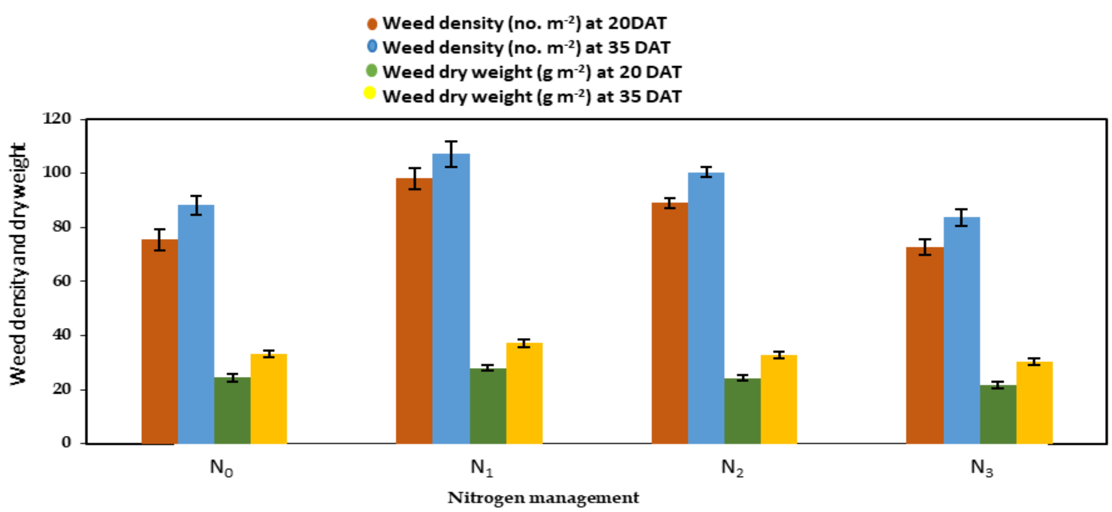

Fig. 2: Effect of nitrogen management on weed density and dry weight

N_1= 100 % of recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

Nandan et al. (2018) also observed variation in weed density and dry weight due to differences in nitrogen management. The lowest weed density and dry weight was found with the application of USG and this might be due to the lower availability of nitrogen to the weed than rice plants and vigorous growth of rice plants.

Interaction effect variety and nitrogen management on weed density and dry weight

Maximum weed density (109.33 m^{-2}) was found in BRRI dhan56 fertilized at 100% of the prescribed rate of prilled urea (150 kg ha^{-1}) at 20 DAT. A similar observation was observed in the same variety with the same prilled urea dose at 35 DAT, with a weed density of (121.33 g m^{-2}) for that variety. The lowest weed density (56.00 m^{-2}) was found in BRRI dhan66 without nitrogen application at 20 DAT and in BRRI dhan66 with a weed density of 68.00 m^{-2} with application of USG at 35 DAT. In case of weed dry weight, at 20 DAT maximum weed dry weight (32.40 m^{-2}) was found in BRRI dhan75 fertilized with 100% of RD of prilled urea but at 35 DAT maximum weed dry weight (42.53 g m^{-2}) was found in BRRI dhan56 with 100% of RD of prilled urea (150 kg ha^{-1}). The lowest weed dry weight (17.46 g m^{-2}) was found in Binadhan-7 with application of USG at 20 DAT and in Binadhan-7 (26.40 g m^{-2}) with application of USG at 35 DAT (Figure 3).

Not only can weeds reduce the amount of N available to crops, but also growth of many weed species is enhanced by higher soil N levels. This can lead to a worst-case scenario where N fertilizer increases the competitive ability of weeds more than that of the crop. Nitrogen released slowly from USG compared to prilled urea and poultry manure which ensured lower availability of nitrogen to the weed during its growth period and favored the growth of rice plant.

Effect of variety on yield and yield contributing characters of T. aman rice

Variety exerted significant influence on almost all yield and yield contributing characters of rice except number of grains $panicle^{-1}$ and harvest index (Table 1). Result indicated that the variety Binadhan-7 exhibited tallest plant (103.33 cm) which was at par with all the varieties except BRRI dhan75 which produced the shortest plant (101.8 cm). Variation in plant height might be due to the differences in the genetic makeup of the varieties. This result is consistent with the findings of Alam et al. (2012) who also reported a variable plant height existed with the varieties. The highest number of total tillers $hill^{-1}$ (12.83) was found in Binadhan-7 and the lowest (8.58) number of total tillers $hill^{-1}$ was found in BRRI dhan71. Tillering is an important trait for rice production (Badshah et al., 2014). The number of total tillers $hill^{-1}$ varied among the varieties was also reported

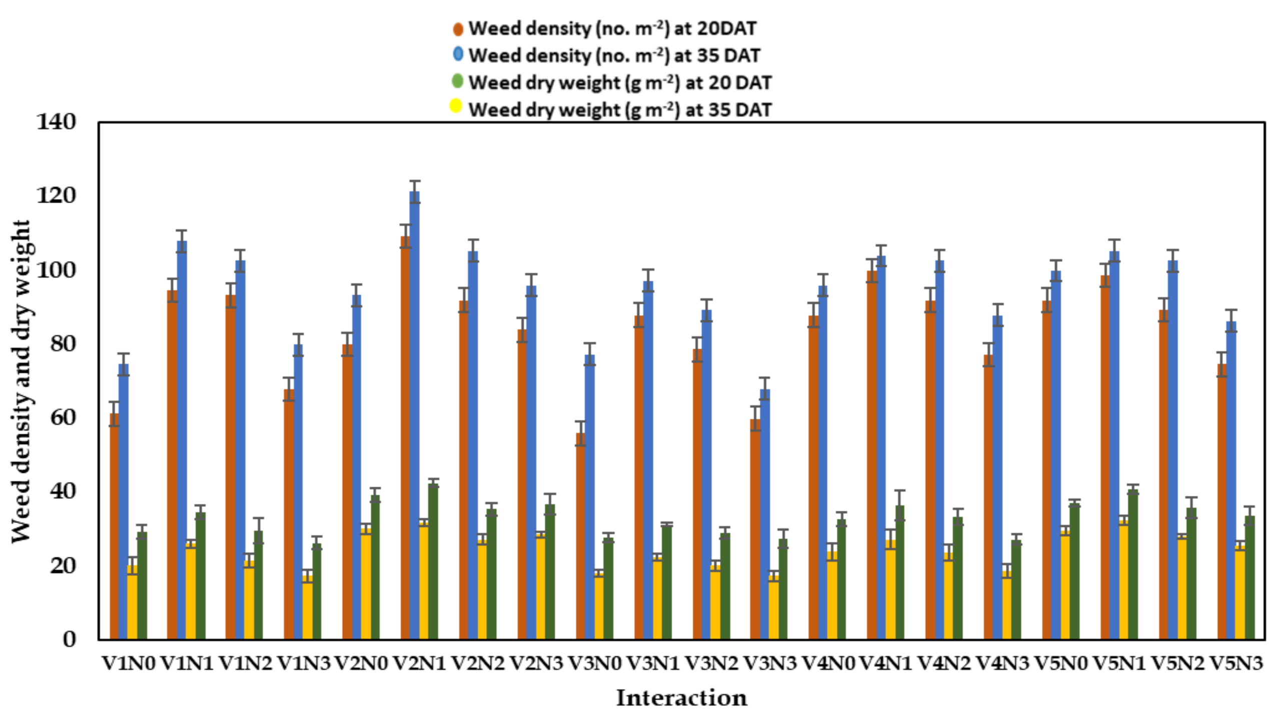

Fig.3: Interaction effect of variety and nitrogen management on weed density and dry weight at 20 and 35 DATs

V_1= Binadhan-7, V_2=BRRI dhan56, V_3= BRRI dhan66, V_4=BRRI dhan71, V_5= BRRI dhan75; N_0= 0 kg N ha^{-1}, N_1= 100 % of recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills) by Karak et al. (2005) and Hossain et al. (2008). The highest number of effective tillers hill^{-1} (10.43) was found in Binadhan-7 and the lowest (7.03) number of effective tillers hill^{-1} was found in BRRI dhan71. Differences in number of effective tillers hill^{-1} among the varieties was also reported by Tyeb et al. (2013) and Chamely et al. (2015). The reasons for differences in producing effective tillers hill^{-1} might be due to the variation in genetic make-up of the variety that might be influenced by heredity. Binadhan-7 produced the longest panicle (23.49 cm) and the shortest panicle was produced by BRRI dhan75 (22.02 cm). Differences in panicle length among genotypes were also stated by Kabir et al. (2004). Variety BRRI dhan66 produced maximum number (23.30) of sterile spikelets panicle^{-1} than the other varieties and Binadhan-7 produced the minimum number (13.30) of sterile spikelets panicle^{-1}. Alam (2013) stated that number of sterile spikelets panicle^{-1} showed significant relation with varieties. Binadhan-7 produced the maximum (22.12 g) 1000-grain weight and the lowest (20.18 g) 1000-grain weight was found in BRRI dhan75. Mou et al. (2017), Afroz et al. (2019) and Salam et al. (2020) also found variation in 1000-grain weight among the cultivars used. They opined that the variation in 1000-grain weight among the cultivars might be due to the genetic constituents of the cultivars. Binadhan-7 produced the highest grain yield (4.42 t ha^{-1}) than the other varieties and BRRI dhan66 produced the lowest grain yield (3.87 t ha^{-1}). Similar research finding was also reported by Ahmed et al. (2021) who observed higher grain yield in Binadhan-7 than BRRI dhan34 in *aman* season in northeastern region. Similarly, Binadhan-7 produced the highest straw yield (5.47 t ha^{-1}), which was similar with rest of the varieties except BRRI dhan75 which produced the lowest straw yield (5.03 t ha^{-1}). Variation in straw yield was also reported by Akando (2007) and Gawali et al. (2015) and this was might be due to genetic heredity of the cultivars. The result of the study reveals that Binadhan-7 produced the highest biological yield (9.90 t ha^{-1}) and BRRI dhan75 produced the lowest biological yield (9.05 t ha^{-1}) (Table 1).

Table 1. Effect of variety on the yield and yield contributing characters of T. *aman* rice

Variety	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets Panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Binadhan-7	103.33a*	12.83a	10.43a	23.49a	105.76	13.30d	22.12a	4.42a	5.47a	9.90a	44.12
BRRI dhan56	102.67ab	9.69b	7.83b	22.52b	103.83	15.61c	22.04a	4.01b	5.30ab	9.32b	42.7
BRRI dhan66	102.47ab	8.72c	7.16c	22.19b	105.69	23.30a	21.12b	3.87b	5.43a	9.31b	41.4
BRRI dhan71	103.25a	8.58c	7.03c	22.38b	104.17	19.81b	21.86a	3.89b	5.42a	9.31b	41.49
BRRI dhan75	101.80b	10.19b	7.96b	22.02b	103.53	15.10cd	20.18c	4.02b	5.03b	9.05b	44
Level of significance	*	**	**	**	NS	**	**	**	**	**	NS
CV%	1.20	9.83	8.15	4.15	4.06	14.89	3.09	9.62	8.51	6.99	7.78

*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)

*= Significant at 5% level of probability, ** =Significant at 1% level of probability, NS = Non significant

V_1= Binadhan-7, V_2=BRRI dhan56, V_3= BRRI dhan66, V_4=BRRI dhan71, V_5= BRRI dhan75

Effect of nitrogen management on yield and yield contributing characters of T. aman rice

Nitrogen management exerted significant impact on all crop characters and yield of rice. The tallest plant (103.80 cm) was found in combine application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea and the shortest plant (100.76 cm) was found in control treatment (Table 2). Due to application of nitrogen fertilizer, plants develop more quickly, their internodes become longer and more numerous, and this results in a gradual rise in plant height. Malik et al. (2014) also recorded a positive effect of nitrogen management on plant height. The maximum number (10.84) of total tillers hill^{-1} was found with combine application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of urea fertilizer and the lowest number (8.73) of total tillers hill^{-1} was found in without nitrogen application. Salem et al. (2011) also recorded a positive effect of nitrogen management on number of total tillers hill^{-1}. The maximum number (9.30) of effective tillers hill^{-1} was found in combine application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea which was statistically similar with other nitrogen treatments except control in which lowest number (4.95) of effective tillers hill^{-1} was found. The longest panicle (23.47 cm) was found with the application of USG and the shortest panicle (21.41 cm) was found in control (no nitrogen) treatment. Tari et al. (2007) also found variation in panicle length due to different nitrogen fertilization. Nitrogen nutrient takes part in the panicle formation as well as panicle elongation and for this reason, panicle length differs with different nitrogen management and application of USG may ensure better availability of nitrogen to the plant so it may produce longest panicle than other nitrogen management. The maximum number of grains panicle^{-1} (111.13) was also found with the application of USG which was statistically similar with 100% of recommended dose of prilled urea (108.40) and the minimum number (91.09) of grains panicle^{-1} was found in control treatment. Rahman et al. (2007) and Hossain et al. (2010) reported variation in number of grains panicle^{-1} due to different nitrogen management. The maximum number of sterile spikelets panicle^{-1} (20.31) was found in control where no nitrogen was applied and the minimum number (14.91) of sterile spikelets panicle^{-1} was found in 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea. Combine application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea produced maximum (22.12 g) 1000-grain weight and the lowest (20.23 g) 1000-grain weight was produced in control (0 kg N ha^{-1}) treatment. Hossain and Islam (2008) also reported the variation in 1000-grain weight due to different nitrogen management. N has a significant influence in raising the protein content, which in turn raises grain weight, as noted by Chaturvedi (2005). Application of USG produced the highest grain yield (4.67 t ha^{-1}) and the lowest grain yield was found in control treatment (2.73 t ha^{-1}). The highest grain yield was obtained from USG. Similar results were found elsewhere (Ahmed et al., 2000; Qurashi et al., 2013). This possibly happened due to the uptake of N by root of the rice plant that influenced the photosynthesis process and subsequently storage of starch in sink cell such as grain (Sarker et al., 2020). The highest straw yield (5.75 t ha^{-1}) was obtained with 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea and the lowest straw yield (4.79 t ha^{-1}) was found in control treatment. Application of nitrogen encouraged vegetative growth of rice in terms of plant height and number of total tillers hill^{-1}, which ultimately resulted in the increase of straw yield (Mishra et al., 2003). The highest (10.15 t ha^{-1}) biological yield was obtained with combine application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea and the lowest biological yield was found in control (7.52 t ha^{-1}) treatment. Lower nitrogen level decreased the grain, straw and biological yields as mentioned by Alam (2006). Similar result was also reported by Dutta et al. (2002). Application of urea super granule (USG) produced the maximum (46.88%) harvest index which was statistically similar with 100% of recommended dose of prilled urea (44.43%) and the lowest (36.37%) harvest index was produced in control (0 kg N ha^{-1}) treatment (Table 2). Nitrogen management influences the grain and straw yields of rice thus resulted in variation in harvest index. This finding corroborates the finding of Sarker et al. (2020) who observed that nitrogen exerted significant variation in harvest index of rice.

Table 2. Effect of nitrogen management on the yield and yield contributing characters of T. *aman* rice

Nitrogen	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets Panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0	100.76b*	8.73b	4.95b	21.41c	91.09c	20.31a	20.23c	2.73b	4.79c	7.52b	36.37c
N_1	103.37a	10.26a	8.95a	22.78ab	108.40ab	16.62bc	21.90ab	4.39a	5.49ab	9.88a	44.43ab
N_2	103.80a	10.84a	9.30a	22.43b	107.75b	14.91c	22.12a	4.40a	5.75a	10.15a	43.29b
N_3	102.89a	10.17a	9.12a	23.47a	111.13a	17.86b	21.61b	4.67a	5.29b	9.96a	46.88a
Level of significance	**	**	**	*	*	**	**	**	**	**	**
CV%	1.20	9.83	8.15	4.15	4.06	14.89	3.09	9.62	8.51	6.99	7.78

*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). *= Significant at 5% level of probability, ** =Significant at 1% level of probability

N_0= 0 kg N ha^{-1}, N_1= 100 % recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

Interaction effect of nitrogen management on yield and yield contributing characters of T. aman rice

The interaction between variety and nitrogen management significantly influenced yield and yield attributes of rice (Table 3). The tallest plant (104.43 cm), highest number of total tillers hill^{-1} (13.77), highest 1000-grain weight (23.16 g) and lowest sterile spikelets panicle^{-1} (11.44) were obtained from Binadhan-7 with application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea. The highest number of effective tillers hill^{-1} (12.43), longest panicle (24.11 cm) and straw yield (5.90 t ha^{-1}) were produced by Binadhan-7 fertilized with 100% of recommended dose of prilled urea. Binadhan-7 with application of USG produced maximum number of grains panicle^{-1} (116.60), highest grain yield (5.21 t ha^{-1}) and biological yield (10.94 t ha^{-1}). Frequently use of prilled urea (PU) helped to increase NH_4^+-N content in soil. But the dynamics of N was not similar during entire growth period of rice by PU fertilizer. USG produced NH_4^+-N slowly and steadily due to deep placement by keeping most of urea nitrogen in the soil, close to plant roots. This resulted in continuous supply of available nitrogen throughout the growth period of rice plant, which ultimately gave the higher grain yield. The interaction of BRRI dhan75 and application of USG produced the highest harvest index (49.44). The shortest plant (99.89 cm), lowest number of total tillers hill^{-1} (7.77), 1000-grain weight (19.10 g) and harvest index (34.05%) were produced by BRRI dhan66 with control (no N) treatment. The shortest panicle (20.86 cm) was produced from the interaction of BRRI dhan56 with control (no N) treatment. The lowest number of grains panicle^{-1} (85.87) was produced by Binadhan-7 with control (no N) treatment and the lowest number of effective tillers hill^{-1} (4.87), grain yield (2.71 t ha^{-1}), straw yield (4.34 t ha^{-1}) and biological yield (7.06 t ha^{-1}) were obtained from BRRI dhan75 with control (no N) treatment (Table 3).

Table 3. Interaction effect of variety and nitrogen management on the yield and yield contributing characters of T. *aman* rice

Interaction	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets Panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1N_0	100.67def*	10.55bc	5.10f	22.81a-d	85.87g	16.08d-g	19.90gh	2.72e	4.48fg	7.20d	37.71efg
V_1N_1	104.22ab	13.33a	12.43a	24.11a	112.16abc	13.11gh	22.98ab	4.84abc	5.90a	10.74ab	44.99abc
V_1N_2	104.43a	13.77a	12.00a	23.96ab	108.41b-e	11.44h	23.16a	4.93ab	5.77abc	10.71ab	46.12abc
V_1N_3	104.00ab	13.67a	12.20a	23.08abc	116.60a	12.59gh	22.45abc	5.21a	5.73abc	10.94a	47.65ab
V_2N_0	100.11f	8.22gh	4.90f	20.86f	90.96g	16.79d-g	21.48cde	2.74e	4.67efg	7.41d	36.94fg
V_2N_1	103.56ab	10.11b-e	8.44cde	22.47b-e	109.36b-e	15.53e-h	22.33abc	4.33bcd	5.45a-d	9.79bc	44.26abc
V_2N_2	103.67ab	10.44bcd	8.97bcd	22.87a-d	107.52b-e	13.63gh	22.35abc	4.39bcd	5.79abc	10.19abc	43.12b-e
V_2N_3	103.33ab	10.00c-f	9.00bc	23.88ab	107.47b-e	16.49d-g	22.01bcd	4.61a-d	5.30a-e	9.90abc	46.47abc
V_3N_0	99.89f	7.77h	5.01f	21.06ef	89.75g	27.93a	19.10h	2.73e	5.37a-e	8.10d	34.05g
V_3N_1	103.33ab	9.00c-h	8.00cde	22.96a-d	111.66a-d	22.03bc	21.85cd	4.33bcd	5.34a-e	9.68bc	44.76abc
V_3N_2	103.67ab	8.89d-h	7.77e	20.91f	107.75b-e	18.14c-f	22.15abc	4.13d	5.87ab	10.00abc	41.25c-f
V_3N_3	103.00abc	9.22c-h	7.88e	23.84ab	113.61ab	25.10ab	21.40cde	4.31bcd	5.15b-f	9.46c	45.54abc
V_4N_0	102.67a-d	7.65h	4.90f	21.24ef	99.03f	21.91bc	21.05def	2.74e	5.09c-f	7.83d	35.02g
V_4N_1	103.56ab	8.77e-h	7.78e	22.14c-f	104.14ef	18.49cde	22.15abc	4.11d	5.39a-e	9.50c	43.28bcd
V_4N_2	103.78ab	9.44c-g	7.89de	22.91a-d	106.97b-e	18.51cde	22.23abc	4.21cd	5.72abc	9.94abc	42.37b-f
V_4N_3	103.00abc	8.44fgh	7.55e	23.25abc	106.54cde	20.34cd	22.03bcd	4.53bcd	5.46a-d	10.00abc	45.31abc
V_5N_0	100.45ef	9.44c-g	4.87f	21.09ef	89.87g	18.83cde	19.65gh	2.71e	4.34g	7.06d	38.12d-g
V_5N_1	102.20b-e	10.11b-e	8.11cde	22.20c-f	104.69def	13.93fgh	20.20fg	4.36bcd	5.36a-e	9.72bc	44.85abc
V_5N_2	103.45ab	11.67b	9.88b	21.51def	108.11b-e	12.85gh	20.71efg	4.32bcd	5.60abc	9.93abc	43.57bcd
V_5N_3	101.11c-f	9.55c-g	9.00bc	23.27abc	111.45a-d	14.78e-h	20.18fgh	4.69a-d	4.81d-g	9.50c	49.44a
Level of significance	**	**	**	**	**	*	**	**	**	**	**
CV%	1.20	9.83	8.15	4.15	4.06	14.89	3.09	9.62	8.51	6.99	7.78

*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); *= Significant at 5% level of probability, ** =Significant at 1% level of probability.
V_1= Binadhan-7, V_2=BRRI dhan56, V_3= BRRI dhan66, V_4=BRRI dhan71, V_5= BRRI dhan75; N_0= 0 kg N ha^{-1}, N_1= 100 % of recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

Relationship between grain yield and yield attributing traits

To assess relationship between grain yield and yield attributing traits simple correlation coefficient were worked out. The positive correlation between grain yield and yield attributing traits like number of effective tillers hill^{-1} (R^2 = 0.83), number of grains panicle^{-1} (R^2 = 0.85), biological yield (R^2 = 0.92) and harvest index (R^2 = 0.88) were observed (Figure 4-7). This means an increase in number of effective tillers hill^{-1} and number of grains panicle^{-1} resulted in the corresponding increase in the grain yield of transplant *aman* rice varieties. Paudel et al. (2021) reported positive correlation between number of effective tillers hill^{-1} and grain yield. Sarker et al. (1017) also reported significant positive correlation between number of grains panicle^{-1} and grain yield.

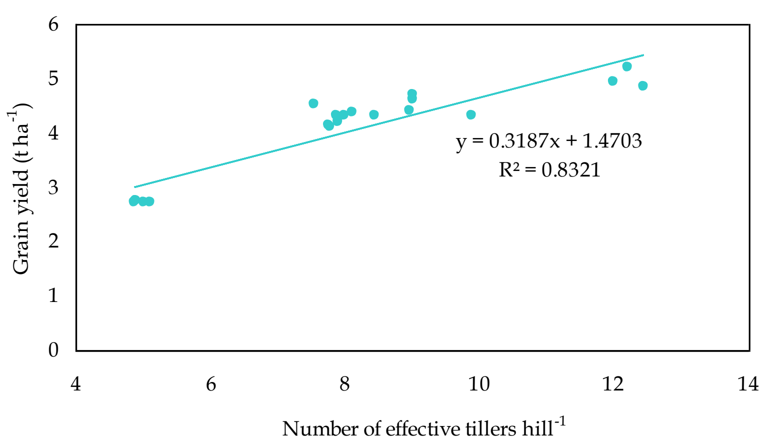

Fig. 4. Relationship between grain yield and number of effective tillers hill^{-1}

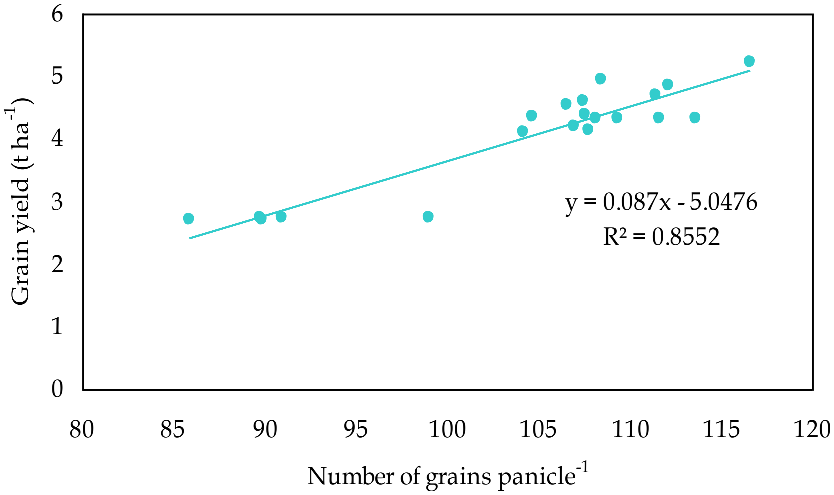

Fig. 5. Relationship between grain yield and number of grains panicle^{-1}

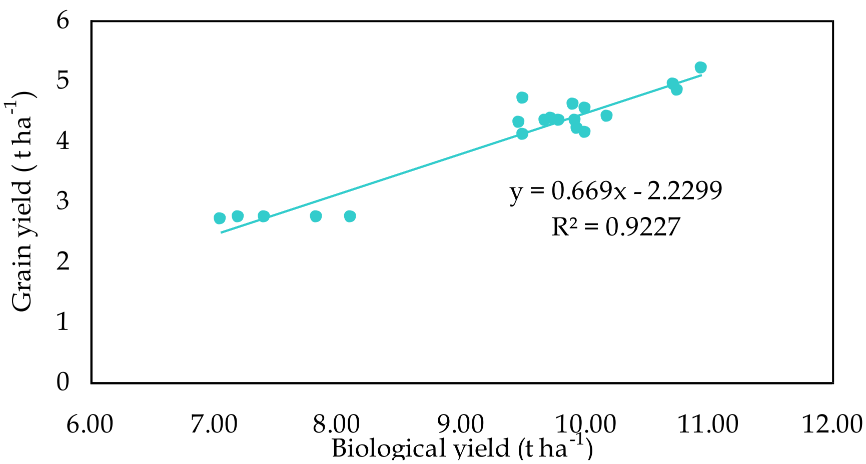

Fig. 6. Relationship between grain yield and biological yield

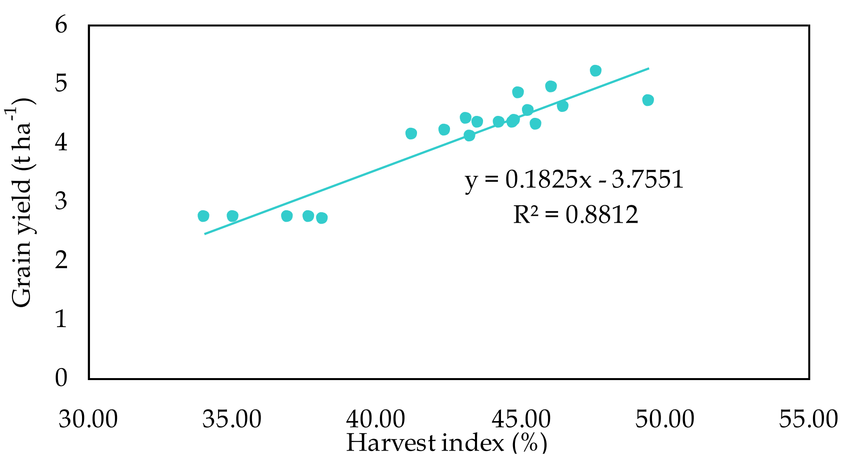

Fig. 7. Relationship between grain yield and harvest index

Nitrogen use efficiency

The nitrogen use efficiency was compared in terms of partial factor productivity (PFP) and agronomic efficiency (AE). Among the varieties the highest value of PFP (53.55 kg grain kg^{-1} N) and AE (24.40 kg grain increased kg^{-1} N) were observed in Binadhan-7. The lowest value of PFP (45.64 kg grain kg^{-1} N) and AE (16.38 kg grain increased kg^{-1} N) were observed in BRRI dhan66 (Table 4). The result shows that PFP (70.52 kg grain kg^{-1} N) and AE (29.29 kg grain increased kg^{-1} N) were higher in application of USG (1.8 g per 4 hills) than the other treatments. On other hand the lowest value of PFP (58.24 kg grain kg^{-1} N) and AE (22.10 kg grain increased kg^{-1} N) were obtained from 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea (Table 5). The highest value of PFP (78.70 kg grain kg^{-1} N) and AE (37.59 kg grain increased kg^{-1} N) were found in Binadhan-7 with application of USG (1.8 g per 4 hills). On the other hand, the lowest PFP (54.70 kg grain kg^{-1} N) and AE (18.53 kg grain increased kg^{-1}) were found in BRRI dhan66 with the application of 2.5 t ha^{-1} poultry manure + 75% of recommended dose of prilled urea (Figure 8-9). Application of USG increased nitrogen use efficiency by keeping most of the nitrogen in the soil, close to plant roots and out of the irrigation water (IFDC, 2007). Kapoor et al. (2008) also observed that significantly higher N use efficiency with deep placement of USG compared to broadcast application of prilled urea.

Table 4. Effect of variety on partial factor productivity and agronomic efficiency

Variety	Partial factor productivity (kg grain kg^{-1} N)	Agronomic efficiency (kg grain increased kg^{-1} N)
Binadhan-7	53.55a*	24.40a
BRRI dhan56	47.62b	18.25ab
BRRI dhan66	45.64b	16.38b
BRRI dhan71	45.94b	16.60b
BRRI dhan75	47.84b	18.79ab
Level of Significance	**	**
CV%	8.87	12.55

*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** =Significant at 1% level of probability

Table 5. Effect of nitrogen management on partial factor productivity and agronomic efficiency

Nitrogen management	Partial factor productivity (kg grain kg^{-1} N)	Agronomic efficiency (kg grain increased kg^{-1} N)
N_0	-	-
N_1	63.71b*	24.14ab
N_2	58.24c	22.10b
N_3	70.52a	29.29a
Level of Significance	**	**
CV%	8.87	40.55

*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** =Significant at 1% level of probability;

N_0= 0 kg N ha^{-1}, N_1= 100 % recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

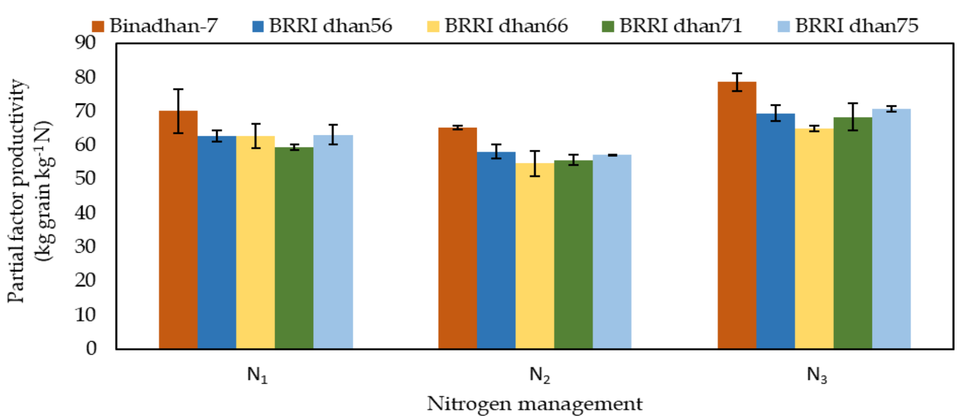

Fig. 8: Partial factor productivity of T. *aman* rice under different nitrogen management

(Here, N_1= 100 % of recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

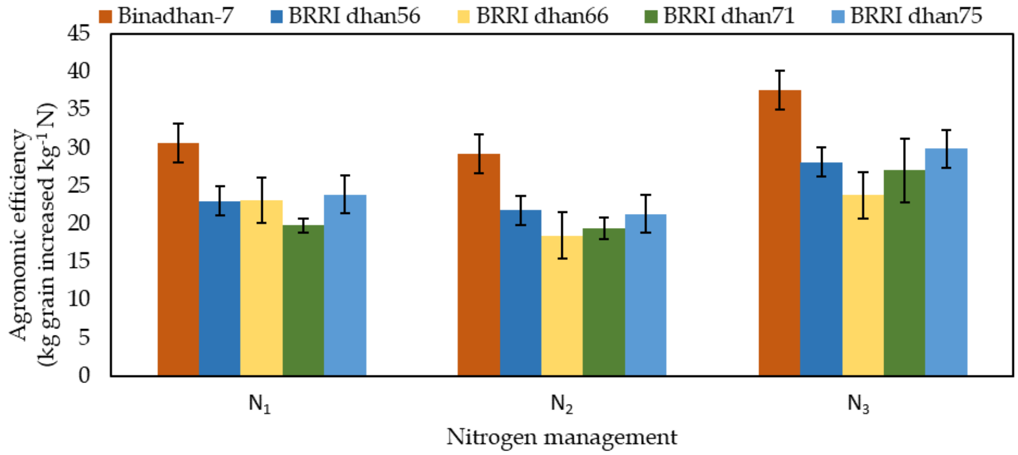

Fig. 9: Agronomic efficiency of T. *aman* rice under different nitrogen management

(Here, N_1= 100 % of recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

Economics of different nitrogen management and variety

To evaluate the economic performance of five transplant *aman* rice varieties *viz*. Binadhan-7, BRRI dhan56, BRRI dhan66, BRRI dhan71 and BRRI dhan75 partial budget analysis was done. The highest net income was obtained from the variety Binadhan-7 with application of USG (BDT 51305 ha^{-1}), the second highest net income was obtained from Binadhan-7 with 100% of recommended dose of nitrogenous fertilizer as prilled urea (BDT 44914 ha^{-1}) and the lowest net income (BDT -5427 ha^{-1}) was obtained in control (without N) treatment along with BRRI dhan75. Considering BCR (benefit cost ratio), it is observed that the highest BCR (1.57) was found in the variety Binadhan-7 with application of USG and the lowest BCR (0.94) was found in BRRI dhan75 variety with control (no nitrogen) treatment (Table 6).

Table 6. Cost effectiveness of T. *aman* rice varieties under different nitrogen management

Variety	(N_0)		(N_1)		(N_2)		(N_3)	
	Net income (Taka)	BCR	Net income (Taka)	BCR	Net income (Taka)	BCR	Net income (Taka)	BCR
Binadhan-7	-3916	0.96	44914	1.50	43969	1.48	51305	1.57
BRRI dhan56	-2681	0.97	31789	1.35	33299	1.36	36510	1.41
BRRI dhan66	1669	1.02	31074	1.34	28619	1.31	29535	1.33
BRRI dhan71	49	1.00	26999	1.29	29244	1.32	35950	1.40
BRRI dhan75	-5427	0.94	31804	1.35	30664	1.33	34925	1.39

N_0= 0 kg N ha^{-1}, N_1= 100 % recommended dose of nitrogenous fertilizer as prilled urea (150 kg ha^{-1}), N_2= 2.5 t ha^{-1} poultry manure + 75% of recommended dose of nitrogenous fertilizer as prilled urea (112.5 kg ha^{-1}), N_3= Application of USG (1.8 g per 4 hills)

Conclusion

Result of this experiment reveals that Binadhan-7 with application of USG (1.8 g per 4 hills) had the lower weed infestation. Binadhan-7 showed superior performance and among different nitrogen management, application of USG (1.8 g per 4 hills) showed the best performance. So, it may be concluded that Binadhan-7 with application of USG (1.8 g per 4 hills) may be used for obtaining highest grain yield with higher nitrogen use efficiency, economic return as well as to minimize weed infestation in *aman* season.

Acknowledgements

The authors are grateful to Ministry of Science and Technology, Government of People's Republic of Bangladesh for financial support through National Science and Technology fellowship.

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