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Evaluation of Seedling Age and Level of Nitrogen on Phenology Yield and Agrometeorological Indices for T-Aman Rice

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Abstracts

Cereal crops are more sensitive toward climate change. Consider this fact a field test was carried out through *aman* season of 2022 at Environmental field of faculty of Agriculture, BAU to study the influence of phenology, yield, and agrometeorological indices for *T-aman* rice. There experiment consist of two factorial RCBD design having seedling age (20, 30, and 40 days old) and nitrogen level (0 kg N/ha, 25 kg N/ha, 46 kg N/ha, and 80 kg N/ha) with three replications. Results showed that *T-aman* rice exhibited higher agrometeorological indices; thermal use efficiencies, grain yield, and straw yield were found in 20-day-old seedlings followed by 30-day-old seedlings, while the lowest values were obtained with 40-day-old seedlings. Moreover, nitrogen being used as a fertilizr management practice increased the agrometeorological indices, thermal use efficiencies, grain yield, and straw yield. The highest values were observed with N3 treatment (80 kg N/ha), followed by N2 (46 kg N/ha), while the lowest values were recorded in the control treatment. Thermal utilization efficiencies showed a strong correlation and regression with biological yield. Therefore, in addition to the heat requirement, the heat utilization efficiency is also a decisive factor for the crop yield.

Keywords: Agrometeorological indices, Phenology, Thermal use efficiencies, *T-aman* rice

Introduction

The economy of Bangladesh is agriculture based and general welfare of the country is largely dependent on sound development of agriculture. Rice (*Oryza sativa* L.) is the leading cereal of the world and it is consumed as staple food about more than 165 million people of Bangladesh (AIS, 2018). In 2021, rice, paddy production for Bangladesh was 56.9 million tons. Rice, paddy production grew by an average yearly rate of 2.89% from 15.1 million tons in 1972 to 56.9 million tons in 2021 (USDA, 2022). The rice which is harvested in the month of November and December is said to be Aman rice. There are two types of *Aman* rice are produced one is known as broadcast *Aman* and is sown in the months of mid-March to mid-April. The other is transplant *Aman* or *T-aman*, which is planted in the months of late June to early August. *T-aman* rice produces 14.44 million metric tons of grain on 5.62 million ha of land (BBS, 2019). Age of seedlings at transplanting is regarded as a crucial element for achieving the rice crop's potential yield (Raoufi et al., 2018). This is due to the fact that seedling ages (SA) can affect a variety of aspects of plant growth and development, including biomass production, tillering, plant height, and crop growth rate (Rajendran and Raja., 2014). According to Pasuquin et al., (2008) transplanting young seedlings results in a larger yield of rice grains than transplanting old seedlings. Nitrogen is the key nutrient element representing two-thirds or more of the total nutrient consumption. Accordingly, the plant must absorb a larger amount of N to produce a higher grain yield. Nitrogen application has tremendous effect on tiller formation and survival of tillers (Rahman et al., 2002). It is a major essential plant nutrient and a key input for increasing crop yield. Yield increase (70-80%) of field rice could be obtained fertilizer with nitrogen is applied. Nitrogen use efficiency for rice crop largely ranges between 25 and 35% and seldom exceeds 50% (Singh and Yadav, 1985). In the cultivation of wetland rice, nitrogen fertilizer effectiveness is quite low. Numerous researches work on nitrogen use efficiency have shown that the efficiency at which nitrogen is utilized in wetland rice is only about 30% of the applied fertilizer N and in many cases even less. The timing of repeating biological occurrences, their causes with regard to biotic and abiotic influences, and the relationships between phases of the same or distinct species are all studied in phenology (Leith, 1974). There are some commonly used indices worldwide among researchers to investigate crop phenology and yield: GDD (growing degree days), HTU (heliothermal unit), PTU (photo thermal unit), HUE (heat use efficiency), PTI (photo thermal index) etc. GDDs (growing degree days) are widely employed as a marker for crop development evaluation because of the close relationship between temperature and plant development. The relationship between temperature and crop development has been discussed by several writers using degree days (Kingra and Kaur, 2012). Additionally, GDD changes as plants grow, making it possible to predict when a specific growth stage would occur in a given site (Master et al., 2012). For assessing the thermal relationship of crops, the thermal units' approach is frequently employed (Ramteke, 1996), and it has since been further developed to incorporate PTU and HTU (Rao et al., 1999). This PTU idea offers a trustworthy indicator of the crop's development that may be used to forecast the yield of any crop. This concept has been used by several authors to compare the performance of different varieties at several dates in different crops (Agarwal et al., 1999). Growing Degree Days and HUE based on temperature are very beneficial for forecasting rice yield and growth. Therefore, the research work was undertaken to evaluate the effect of seedling age on agrometeorological indices, crop phenology and yield of T-Aman rice under different nitrogen levels.

Materials and methods

Location

The experiment was carried out at the experimental field of the Department of Environmental Science, located within the campus of Bangladesh Agricultural University in Mymensingh. The geographical coordinates of the site are latitude 2475 N and longitude 9050 E, with an elevation of 18 meters above sea level. The climate of Mymensingh is tropical, characterized by higher rainfall during summer than winter. The wet season lasts for 6.1 months, starting from April 7 to October 11, with a greater than 40% probability of a wet day. The month of July experiences the highest number of wet days with an average of 23.9 days with at least 0.04 inches of precipitation. On the other hand, the dry season lasts for 5.9 months, starting from October 11 to April 7, with December being the month with the least number of wet days, averaging 0.8 days with at least 0.04 inches of precipitation.

Description of Experimental Plot

Field experiment was conducted on a Randomized Block Design (RBD) with twelve treatments (three seedling age, four nitrogen level) replicated thrice in a 2.5m× 4 m plot. The test crop variety was BRRI Dhan-49. Nitrogen fertilizer were applied in equal three split at the time of final land preparation and 15 and 30 days after transplanting. Others fertilizer like TSP (150 kg/ha), MOP (80 kg/ha), Gypsum (60 kg/ha) and Zinc (10 kg/ha) were applied at final land preparation.

The experimental treatments were as follows:

Factor A: Age of Seedlings

i. 20 days old (S1)

ii. 30 days old (S2)

iii. 40 days old (S3)

Factor B: Level of Nitrogen)

i. 0 Kg N ha^{-1} (N0)

ii. 25 Kg N ha^{-1} (N1)

iii. 46 Kg N ha^{-1} (N2)

iv. 80 Kg N ha^{-1} (N3)

Description of data collection

Recommended intercultural operation practices and plant protection measures were followed to raise the crops. The dates of occurrences of different phenophases (Panicle initiation, 1st flowering, 50% flowering, 100% flowering, physiological maturity etc) were recorded properly. From each plot 3 plants were selected and plant height, leaf area, number of tillers, fresh weight, dry weight, seed per plant, 1000 seed weight etc data were also recorded. The crop harvested from net plot area was converted into seed yield (kg/ha) and biological yield (kg/ha). Various weather health indices were calculated as follows.

Calculation of agrometeorological indices

A degree day or a heat unit is the departure from the mean daily temperature above the threshold temperature of the crop. Growing degree days (GDD) concept assumes that there is a direct and linear relationship between growth of plants and temperatures (Murthy, 2016). This was expressed as °C Day. The GDD were calculated by the following equation (Iwata, 1984).

$$GDD = (T\ max + T\ min)/2 - Tb \quad (1)$$

(T max + T min are daily maximum and minimum temperatures and temperature Tb is the base temperature taken as 10°C).

Heliothermal Units (HTU) = GDD × bright sunshine hours. (2)

Expressed as °C Day hour.

Heat Use Efficiency (HUE) defined as yield per day °C on growing day concept or per unit of day Heat use efficiency defined as yield per day °C on growing day concept or per unit of day °C hours on heliothermal units indicating the efficiency with the available heat utilized for seed yields. This is expressed as kg ha^{-1} °C Day^{-1}.

HUE = Seed Yield kg ha^{-1}/ Accumulated Heat Unit (°C Day) (3)

PTI is defined as the ratio of GDD to the number of days between two phonological stages. It is expressed as °C.

PTI = Accumulated GDD/Number of Days (4)

Statistical analysis

The recorded data were organized and tabulated in a suitable format for subsequent statistical analyses. The collected data underwent statistical analysis through the "Analysis of Variance" technique, employing the R computer program. The assessment of mean differences among the treatments was determined using Duncan's Multiple Range Test (DMRT) and the Least Significant Difference (LSD) Test, as outlined by Gomez and Gomez (1984), as deemed necessary.

Results and Discussion

Number of Days

The duration of various phenological stages was significantly influenced by the seedling age, and level of nitrogen as indicated in **Table 1**. Young seedlings required a greater number of days to progress through distinct phenological stages, such as panicle initiation and maturation, while older seedlings exhibited accelerated advancement through these stages. In terms of nitrogen levels, the highest nitrogen concentration prolonged the time required to reach different phenological stages, such as 50% flowering and maturity, whereas the control treatment exhibited the shortest duration. Transplant shock experienced by seedlings in an open field, coupled with the expedited growth of older seedlings, led to an increased transpiring surface area, resulting in greater transpiration losses and diminished crop performance. The observed outcomes align with the findings of Adesina et al. (2014), Biswas et al. (2009), and Kumar et al. (2014). The prolonged duration for reaching various phenological stages with higher nitrogen levels can be attributed to the increased number of calendar days resulting from elevated nitrogen application. These results find support in the research of Praveen et al. (2013).

Table 1. Effect of seedling age on days taken to attain various growth stages of T Aman rice under different level of nitrogen

Treatment	Number of Days		
Age of seedling	Panicle Initiation	50% Flowering	Mature
S1:	36.16 a	77.75 a	106.83 a
S2:	36.00 a	77.41 a	106.50 a
S3:	36.08 a	78.16 a	104.75 b
CV (%)	2.37	1.37	1.28
LSD (5%)	0.72	0.90	1.15
Nitrogen rate			
N0:	36.11 a	75.77 c	93.00 d
N1:	36.44 a	78.22 ab	108.55 b
N2:	36.00 a	78.00 b	106.66 c
N3:	35.77 a	79.11 a	115.88 a
CV (%)	2.37	1.37	1.28
LSD (5%)	0.83	1.04	1.33

Growing Degree Days (GDD)

Table 2 presents data on GDD during various phenological phases of *T-aman* rice. The highest heat unit requirements for Panicle Initiation (PI) occur at the lowest seedling age, with the maximum GDD value observed in older seedlings for the 50% flowering stage. Conversely, at the mature stage, the maximum GDD is found in the youngest seedlings. Specifically, 20-day-old seedlings accumulate the significantly highest GDD of 741.1 (°C Day) to attain PI. Similarly, for achieving 50% flowering and maturity, 40-day-old and 20-day-old seedlings accumulate the significantly highest GDD of 1550.6 and 2010.86 (°C Day), respectively. The decline in GDD with an increase in seedling age is attributed to the stress experienced by mature seedlings, resulting in forced maturity and reduced growth duration (Adesina et al., 2014). Regarding nitrogen levels, the maximum GDD for PI is found at the lower nitrogen level. For 50% flowering, the maximum GDD is observed at the highest nitrogen level, and for the mature stage, the highest GDD is recorded at the highest nitrogen level. This is attributed to the consistent availability of nutrients throughout the growth period, leading to an extended crop period and the accumulation of more heat units.

Heliothermal Unit (HTU)

The accumulation of heliothermal unit (HTU) by *T-aman* rice to achieve various phenological stages, under different seedling ages, exhibited a range of 4356.25 to 4359.90°C Day-hour for the Panicle Initiation (PI) stage, 8627.03 to 8755.34°C Day-hour for the 50% flowering stage, and 12965.58 to 13324.21°C Day-hour for the mature stage. The maximum HTUs, recorded at 4359.90 and 13324.21°Cday-hour for PI and maturity stages, respectively, were associated with transplanting 20-day-old seedlings, emphasizing the significance of the crop growth period. Younger seedlings, as compared to older ones, accumulated more heat units due to their extended growth and crop duration, as highlighted in the findings of Adesina et al. (2014). The accumulation of HTUs varied significantly among different nitrogen levels. The application of 100 kg N/ha resulted in higher HTUs during the 50% flowering and mature stages. These results are supported by the findings of Perves et al. (2020).

Table 2. Accumulated GDD and HTU at different growth stages of T-Aman rice

Treatment	GDD (°C day)			HTU (°C day hour)		
Age of seedling	PI	50 % Flowering	Mature	PI	50 % Flowering	Mature
S1:	741.2	1542.3	2010.86 a	4359.90	8694.03	13324.21 a
S2:	738.6	1535.4	2008.27 a	4356.25	8627.03	13284.46 a
S3:	739.4	1550.6	1987.58 b	4357.32	8755.43	12965.58 b
CV (%)	2.11	1.3	0.91	0.42	2.07	2.26
LSD (5%)	13.62	17.56	15.44	15.55	147.80	252.99
Nitrogen rate						
N0	740.17	1503.86 c	1802.22 d	4357.51	8361.27 c	10621.95 d
N1	746.12	1551.70 ab	2043.22 b	4365.59	8763.96 ab	13874.31 b
N2	738.14	1547.54 b	2017.07 c	4356.50	8721.36 b	13519.33 c
N3	734.23	1568.55 a	2139.77 a	4351.70	8922.06 a	14750.07 a
CV (%)	2.11	1.34	0.91	0.42	2.0	2.26
LSD (5%)	15.25	20.77	17.86	17.96	170.66	292.13

Hydrothermal Unit (HyTU)

The age of seedlings resulted in notable variations in the accumulation of hydrothermal units during the growth period of Taman rice at different phenological stages. The HyTU accumulated to reach the stages of PI, 50% flowering, and maturity ranged from 61,132.28 to 61,410.73, 130,195.8 to 131,339.7, and 167,255.8 to 169,39.6, respectively (**Table 3**). Similarly, distinct levels of nitrogen induced significant variations in the accumulation of hydrothermal units during the growth period of Taman rice at various phenological stages. The amount of HyTU accumulated to reach PI, 50% flowering, and maturity stage ranged from 60,764.93 to 61,868.29, 127,626.4 to 132,787.9, and 152,227.8 to 180,078.3, respectively. Similar result was found by Perves et al. (2020) for the agrometeorological indices in rabi maize.

Table 3. Accumulated HyTU and thermal use efficiencies at different growth stages of T-Aman rice

Treatment	HyTU (°C day%)			Thermal use efficiency		
Age of seedling	PI	50 % Flowering	Mature	HUE	HTUE	HyTUE
S1 :	61410.73	130700	16939.6 a	7.58	1.15	0.08
S2:	61132.28	130195.8	169231.1 a	7.79	1.18	0.09
S3:	61277.98	131339.7	167255.8 b	7.62	1.16	0.09
CV (%)	2.33	1.25	0.90	6.42	6.69	6.45
LSD (5%)	1212.69	1391.37	1298.43	0.42	0.07	0.004
Nitrogen rate						
N0	61325.24	127626.4 c	152227.8 d	7.31 b	1.14 b	0.08 b
N1	61868.29	131456.7 ab	172351.9 b	6.24 c	0.92 c	0.07 c
N2	61136.20	131109.7 b	170177.3 c	6.67 c	0.99 c	0.07 c
N3	60764.93	132787.9 a	180078.3 a	10.42 a	1.51 a	0.12 a
CV (%)	2.33	1.25	0.90	6.42	6.69	6.45
LSD (5%)	1400.32	1606.23	1499.31	0.48	0.07	0.005

Thermal use efficiency

Transplanting 30-day-old seedlings resulted in higher HUE, HTUE, and HyTUE during the stages of PI, 50% flowering, and maturity. The increased values for HUE, HTUE, and HyTUE were attributed to a substantial enhancement in growth observed under the transplantation of 30-day-old seedlings, characterized by greater vigor and attainment of higher growth stages. Among various nitrogen levels, the application of 100 kg N/ha exhibited significantly higher HUE, HTUE, and HyTUE during the stages of PI, 50% flowering, and maturity. It is noteworthy that the heat energy available to the crop was not fully utilized or converted into dry matter. The yield potential of the crop is influenced by multiple factors, including genetic makeup and management practices, which can be evaluated in terms of thermal use efficiency.

Plant height

The effect of age of seedling age on plant height is shown on **Table 4**. Here we found that for 60 DAT and Harvest period plant height decrease in order to older seedlings. Similar results were also found by Pul *et al.* (2003) where it is shown that plant height decreases in order to older seedling. Findings from Paul this reduction in plant height might be due to better growth and vigor of the 20 days old seedlings. The recovery of transplanting shock is much better in younger seedlings compared to older ones. Plant height decrease gradually in older seedling at two sampling dates among the three. Plant height was significantly influenced by level of nitrogen. From the table 4 we found that the highest plant height was obtained from treatment N3 (100 kg N/ha) at different dates of transplanting. A report by Hague *et al*. (2012) showed that plant height increased due to nitrogen application up to a certain level and after this level of nitrogen application plant height decrease.

Table 4. Plant height and tiller of T Aman rice as influenced by age of seedling and level of nitrogen

Treatment	Plant height			Tiller	
Seedling age	30 DAT	60 DAT	Harvest	30 DAT	60DAT
S1:	53.91 a	91.75 a	109.75 a	21.50 a	15.75 a
S2:	57.16 a	91.58 a	107.16 ab	19.50 a	13.83 a
S3:	54.83 a	88.50 b	103.166 b	24.58 a	14.25 a
CV (%)	7.51	3.22	4.45	27.65	17.85
LSD (5%)	3.51	2.47	4.02	5.11	2.2
Nitrogen rate					
N0:	53.77 ab	85.11 b	99.44 c	21.55 a	12.22 b
N1:	56.22 ab	86.88 b	108.88 b	20.11 a	14.77 a
N2:	53.44 b	94.33 a	99.88 c	22.33 a	16.66 a
N3:	57.77 a	96.11 a	118.55 a	23.44 a	14.77 a
CV (%)	7.51	3.22	4.45	27.65	17.85
LSD (5%)	4.06	2.85	4.65	5.9	2.55

Leaf Area Index (LAI)

It was found that leaf area index did not change significantly with seedling ages at different sampling dates. At 30 DAT LAI was similar for all seedling types whereas at 60 DAT higher LAI value was found for 20 days old seedlings than the older seedlings (**Fig. 1 a**). Leaf area index gradually increased with the increase of time irrespective to the seedling whether it is young or old (Alam, 2018). LAI significantly changed with level of nitrogen in different sampling dates. Both 30 DAT and 60 DAT higher LAI value were found at 100 kg N ha^{-1} nitrogen level followed by 46 kg N ha^{-1}.

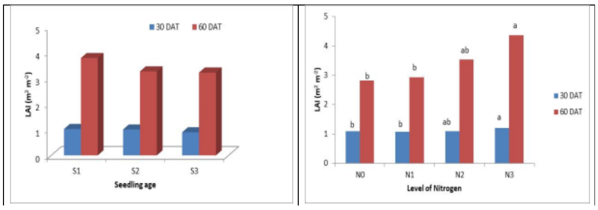

Fig. 1. a) Effect of seedling age and b) level of nitrogen on leaf area index of T-aman rice at different dates of sampling

Grain yield

The interaction among level of nitrogen and age of seedlings for grain yield of *T-aman* is shown in **Fig. 2**. It was found that interaction of 46 kg N/ha and 20 days old seedlings produced the maximum grain yield 100 kg N/ha also had similar yield with 20 days seedlings (**Fig. 2**). This finding is in agreement with that of Upadhyay *et al.* (2003) and Singh and Singh (1998). Older seedlings remained more days in the nursery bed and as a result basal node was formed in the seedlings. Again, it took more time to establish in the main field. On the contrary, the younger seedlings got less time in the nursery bed and thus nodes were not formed and they quickly recovered the transplanting shock in the main field. Thus, they started to regrowth quickly which ultimately helped to work in favour of better growth of plant, and yield components and yield. Once more, panicle initiation occurred earlier in the plant, and more spikelets developed, increasing the number of spikelets per panicle. As a result, the yield factors were enhanced and the sterility percentage was reduced, which was mostly responsible for the enhancement of grain production. Application of 46 kg N/ha encouraged the vegetative growth of rice in terms of plant height, number of effective tillers per hill, which ultimately resulted in increase of grain yield. Similar result was observed by Uddin *et al.* (2013), Salam *et al.* (2004).

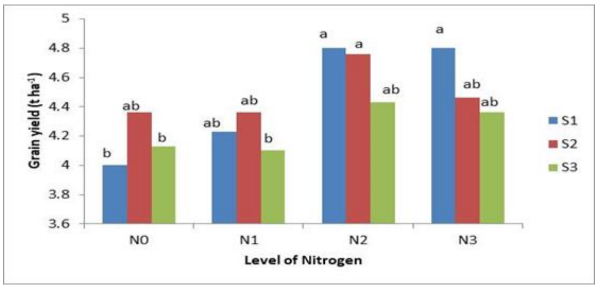

Fig. 2. Interaction of level of nitrogen and age of seedlings with grain yield of T-aman rice

Regression analysis

The coefficient of determination ranged from 0.2769 to 0.9539 indicating the response of biological yield to agro-meteorological indices. HUE accounted for maximum variability of 95% in biological yield. GDD explained 35% in biological yield whereas HTU and HTUE explained 27% and 76% in biological yield respectively. Thermal use efficiencies showed maximum values for coefficient of determination against biological yield. This clearly indicates the closeness of association between thermal use efficiency and biological yield of *T-aman* rice. Thus, it can be concluded that apart from heat requirement, heat utilization efficiency acts as a key determinant of crop yield. These results are supported by the findings of Amgain (2013) and Tauseef *et al.* (2015).

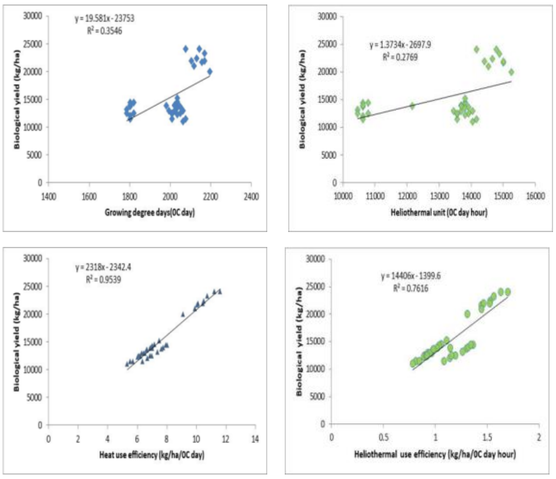

Fig. 3. Linear regression equations fitted to explain of agrometeorological indices on biological yield of T Aman rice

Conclusions

It was found that both seedling age and nitrogen level had an impact on the growth, yield of *T-aman* rice. The research demonstrated that applying 46 kg N/ha of nitrogen fertilizer showed higher influence on plant growth, yield and related characteristics. However, exceeding this dosage did not result in any increase, in yield. The study also found that using seedlings of 30 days old is the effective for promoting plant growth, yield and related characteristics. To sum up the research suggests that farmers and researchers looking to improve *T-aman* rice productivity in the Old Brahmaputra Floodplain and Agro-ecological zone (AEZ 9) of Bangladesh should consider using 30-day seedlings and applying nitrogen fertilizer at a rate of 46 kg N/ha. These findings have implications, for enhancing *T-aman* rice production in this region.

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