Morpho-physiological attributes of three HYV aromatic fine rice varieties as affected by integrated nutrient management

S.K. Sarkar, M.A.R. Sarkar, N. Islam and S.K. Paul
Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
Email: shubroto.252@gmail.com

Abstract: An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the morpho-physiological attributes of three HYV aromatic fine rice varieties as affected by integrated nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38; and eight nutrient managements viz. control (no manures and fertilizers), recommended dose of inorganic fertilizers, cowdung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of recommended dose of inorganic fertilizers + 50% cowdung, 50% of recommended dose of inorganic fertilizers + 50% poultry manure, 75% of recommended dose of inorganic fertilizers + 50% cowdung and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The experiment was laid out in a randomized complete block design with three replications. BRRI dhan34 produced the tallest plant (115.8cm) at 85 DAT whereas the highest number of total tillers $hill^{-1}$(14.56) was found at 70 DAT in the same variety. The highest leaf area index (LAI) (5.431) and the highest amount of total dry matter (TDM) production $hill^{-1}$ (49.47 g $hill^{-1}$) were found at 70 DAT in BRRI dhan34. Crop growth rate (CGR) (30.47 g m^{-2} day^{-1}) was found highest at 55-70 DAT in BRRI dhan34.On the other hand, application of 75% of recommended dose of inorganic fertilizers + 50% cowdung resulted in the highest plant height (123.3 cm) at 85 DAT, the highest number of total tillers $hill^{-1}$ (15.57) and the highest LAI (6.050) at 70 DAT, the highest amount of TDM accumulation (59.91 g $hill^{-1}$) at 85 DAT and the highest CGR (41.65 g m^{-2} day^{-1}) at 55-70 DAT. The interaction effect between BRRI dhan34 and 75% of recommended dose of inorganic fertilizers + 50% cowdung produced the tallest plant (127.0 cm) at 85 DAT, the highest number of total tillers $hill^{-1}$ (16.2) and the highest LAI (6.4) at 70 DAT and the highest CGR (46.96 g m^{-2} day^{-1}) at 55-70 DAT. Grain yield showed significantly positive correlation with leaf area index (r = 0.929**) and total dry matter production (r = 0.948**) at 70 DAT.
Key words: Integrated nutrient management, fine rice, LAI, TDM, CGR.

Introduction

Rice (*Oryza sativa*) is the most dominating cereal crop in Bangladesh and it is the staple food of most of the Bangladeshis. It is mainly produced and consumed in Asia which constitutes more than half of the global population (Chakravarthi and Naravaneni, 2006) and plays a unique role in combating global hunger (IRRI, 2004). Aromatic fine rice is the most highly valued rice commodity in agricultural trade market having small grain, pleasant aroma with soft texture upon cooking. Because of its natural chemical compounds which give it a distinctive scent or aroma when cooked, aromatic rice commands a higher price than non-aromatic rice. In recent years, aromatic rice has been introduced to the global market. It has great potential to attract rice consumer for its taste and deliciousness, and high price to boost up the economic condition of the rice grower in the developing countries like Bangladesh. Nevertheless, the higher prices and export quality of aromatic fine rice warrant their higher production. Like other crops, the yield level of rice, the staple food grain of the country, is very low (2.91 t ha^{-1}) (BBS, 2011) compared to other rice growing countries like South Korea and Japan where the average yield is 6.00 and 5.22 t ha^{-1} respectively (FAO, 2004). The probable reasons for low yield may be improper selection of suitable variety and inadequate growth of the crop plants. A good soil should have at least 2.5% organic matter but in Bangladesh, most of the soils have less than 1% organic matter which is also declining day by day (BARC, 1997). Nutrient mining and soil organic matter reduction in soil aggregates etc. have been identified as reasons of yield stagnation or decline in the productivity of crops (Rahman and Yakupitiyage, 2006). Application of cowdung and poultry manure may play an important role in rice cultivation when used alone or in combination with chemical fertilizers (Islam, 2014). It is known that poultry litter can be utilized for rice production (BRRI, 2006). Cowdung contains 05-1.5% N, 0.4-0.8% P, 0.5-1.9% K and other nutrients in small quantity while the poultry manure contains high amount of secondary and micronutrients in addition to 1.6% N, 1.5% P and 0.85% K. In addition it may supply sufficient amount of S, Zn and B for growth of rice plant. Global environment pollution can be controlled considerably by reducing the use of chemical fertilizers and increasing the use of cowdung and poultry manure. Though rice is one of the most important crops of the world, enough information regarding the varieties of aromatic fine rice and their growth response to cowdung and poultry manure are scarce in the world literature. Therefore, it is required to find out the right variety and a suitable nutrient management involving organic and inorganic fertilizers which would supply nutrients to the plants in adequate amount. In the light of this concept, the present experiment was conducted to observe the growth response of aromatic fine rice varieties to nutrient management.

Materials and Methods

The research work was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, belongs to the Sonatola series of the dark grey floodplain soil type under Old Brahmaputra Floodplain Agro-Ecological Zone (AEZ-9). The field was a medium high land with well drained silty-loam texture having pH 6.5 and 1.67% organic matter. The experiment was laid out in a two factor randomized complete block design with three replications. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRIdhan38 and eight nutrient managements viz. control (no manures and fertilizers), recommended dose of inorganic fertilizers (i.e 150, 97, 70, 60 and 12 kg ha^{-1} urea, TSP, MoP, gypsum and zinc sulphate, respectively), cowdung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of recommended dose of inorganic fertilizers +

50% cowdung, 50% of recommended dose of inorganic fertilizers + 50% poultry manure, 75% of recommended dose of inorganic fertilizers + 50% cowdung and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The nursery beds were puddled with country plough, cleaned and leveled with ladder. Then the sprouted seeds were sown in the nursery beds on 30 June. At the time of final land preparation, respective unit plots were fertilized with whole amount of organic manure, TSP, MoP, gypsum and zinc sulphate. Urea was applied in three equal splits at final land preparation, 30 days after transplanting (DAT) and 50 DAT. Thirty-day old seedlings were transplanted on 1 August with three seedlings hill^{-1}. Growth parameters were recorded from 25 DAT at 15-day intervals upto 85 DAT. To record the data on plant height and number of total tillers hill^{-1} a set of five hills plot^{-1} were marked and recorded the data at 15-days intervals. For destructive sampling five hills (excluding border rows) were selected randomly from each unit plot and uprooted at the 15-day intervals beginning from 25 DAT upto 85 DAT to record the necessary data on LAI and TDM and CGR were calculated by following standard formulae (Radford, 1967 and Hunt, 1978) which are as follows:

Leaf Area Index (LAI): Leaf area index was measured by using an Area Meter at the Professor Muhammad Hussain Central Laboratory, BAU, Mymensingh. LAI = (LA ÷ P), Where, LA = Total leaf area of the leaves of the sampled plants, P = Ground Area (m^2).

Total dry matter hill^{-1}: Five sample plants were uprooted from each plot 15 day intervals up to 85 DAT and were cleaned, de-rooted and leaves were separated from the culms. Before recording the data, collected samples were dried in an electric oven for 72 hours maintaining a constant temperature of 70° C.

Crop Growth Rate (CGR): Rate of dry matter production per unit of time per unit of ground area was calculated with the following formula: $CGR = [(1 \div A)\ \square \{(W_2 - W_1) \div (T_2 - T_1)\}]$ g m^2 day^{-1}. Where, W_1 = dry matter production at T_1 time, W_2= dry matter production at T_2 time, A= Ground Area (m^2).

The collected data were analyzed statistically using the "analysis of variance" technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using MSTAT- C computer program.

Results and Discussion

Plant height: Plants tend to grow to a certain height in each of its growth state (Sritarapipat *et al.*, 2014). BRRIdhan 34 was observed as the tallest plant at all the DATs (Table 1). The highest plant height (115.8cm) was recorded in BRRI dhan34 at 85 DAT. The shortest plant was found in BRRI dhan37 (112 cm) at the same DAT. The variation in plant height among the varieties was probably due to heredity of variety. Similar results were reported elsewhere (Paul *et al.,* 2016; Ray *et al*.,2015 and Kirttania *et al*., 2013).

Nutrient management treatment of 75% of recommended dose of inorganic fertilizers + 50% Cowdung produced the highest plant height (123.3 cm) at 85 DAT (Table 2). The shortest plant (106.2 cm) was obtained from control (no manures and fertilizers) at same DAT. The tallest plant (127.0 cm) was at 85 DAT in BRRIdhan34 × (75% of recommended dose of inorganic fertilizers + 50% cowdung) and the shortest plant (101.7 cm) was found in BRRI dhan37 × control (Table 3).

Table 1. Effect of variety on plant height, number of total tillers hill^{-1} and leaf area index (LAI) at different DAT of aromatic fine rice

Varieties	Plant height (cm)					Number of total tillers hill^{-1}					Leaf area index (LAI)				
	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25DAT	40 DAT	55 DAT	70 DAT	85 DAT
BRRI dhan34	46.46a	75.93a	94.04a	103.5a	115.8a	4.950a	7.968a	12.97a	14.56a	13.69a	1.393a	2.326a	3.539a	5.431a	4.871a
BRRI dhan37	44.33c	67.53c	88.34c	97.85c	112.0c	4.457c	7.314c	11.67c	13.87c	12.79c	1.221c	2.037c	3.051c	4.907c	4.193c
BRRI dhan38	46.02b	69.70b	1.84b	101.7b	114.1b	4.617b	7.558b	12.37b	14.15b	13.29b	1.303b	2.254b	3.319b	5.128b	4.490b
Sx	0.129	0.456	0.272	0.232	0.351	0.029	0.041	0.085	0.042	0.046	0.009	0.014	0.022	0.023	0.030
Level of sign.	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	1.39	3.15	1.46	1.25	1.51	3.08	2.69	3.39	1.45	1.71	3.31	3.25	3.29	2.19	3.19

Table 2. Effect of nutrient management on plant height, number of total tillers hill^{-1} and leaf area index (LAI) at different DAT of aromatic fine rice

Nutrient management	Plant height (cm)					Number of total tillers hill^{-1}					Leaf area index (LAI)				
	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25DAT	40 DAT	55 DAT	70 DAT	85 DAT
T_1	3.09f	62.42f	85.33f	95.08g	106.2e	4.13f	6.62f	10.67e	12.32g	11.72g	1.007h	1.683g	2.473g	3.669g	3.163f
T_2	6.62b	73.09b	93.25b	101.7c	115.2c	4.77c	8.09b	13.09b	14.90b	13.78bc	1.387c	2.337c	3.583c	5.453c	4.927b
T_3	3.82e	65.11e	88.29e	97.25f	110.0d	4.24ef	6.95e	11.22d	13.23f	12.22f	1.110g	2.010f	2.757f	4.770f	4.083e
T_4	4.69d	67.09 de	90.27d	99.69e	111.1d	4.38de	7.35d	11.60d	13.82e	12.81e	1.247f	2.073ef	3.150e	5.070e	4.290d
T_5	5.36c	68.96cd	90.75cd	100.5de	113.6c	4.48d	7.47d	12.22c	14.19d	13.16d	1.293e	2.137de	3.210e	5.190d	4.570c
T_6	5.74c	70.24 c	91.67c	101.2cd	114.3c	4.69c	7.71c	12.51c	14.61c	13.58c	1.337d	2.197d	3.363d	5.297d	4.693c
T_7	8.38a	86.33a	97.49a	108.5a	123.3a	5.64a	8.47a	14.02a	15.57a	14.81a	1.607a	2.663a	4.020a	6.050a	5.443a
T_8	7.11b	75.20 b	94.20b	104.2b	118.2b	5.04b	8.22b	13.36b	14.92b	13.99b	1.457b	2.547b	3.867b	5.747b	4.973b
Sx	0.211	0.746	0.445	0.378	0.574	0.048	0.068	0.139	0.068	0.076	0.0149	0.023	0.036	0.038	0.048
Level of sign.	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	1.39	3.15	1.46	1.25	1.51	3.08	2.69	3.39	1.45	1.71	3.31	3.25	3.29	2.19	3.19

Number of total tillers hill^{-1}: The tiller production increased with the advancement of time from 25 to 70 DAT but decreased after 70 DAT (Table 1). The highest number of total tillers hill^{-1} (14.56) was recorded in BRRI dhan34 at 70 DAT and thereby decreased to 13.69 at 85 DAT. The lowest number of total tillers hill^{-1} (13.87) was found in BRRI dhan37 at 70 DAT. Nutrient management treatment of 75% of recommended dose of inorganic fertilizers + 50% cowdung produced the highest number of total tillers hill^{-1} (15.57) followed by 75% of recommended dose of inorganic fertilizers + 50% poultry manure at 70 DAT (Table 2). The highest number of total tillers hill^{-1} occurred due to the absorption of more nutrient, moisture and also for availability of more sunlight. The control treatment produced the lowest number of total tillers hill^{-1} (12.32) at 70 DAT. The lowest number of total tillers hill^{-1} occurred due to lack of proper nutrient uptake. Interaction effect of varieties and level of nutrient management produced the highest number of total tillers hill^{-1} (16.2) at 70 DAT in the interaction effect between BRRI dhan34 and 75% of recommended dose of inorganic fertilizers + 50% cowdung BRRI dhan38 × 75% of recommended dose of inorganic fertilizers + 50% cowdung and BRRI dhan34 × 75% of recommended dose of inorganic fertilizers + 50% poultry manure, respectively (Table 3). The lowest of number of total tillers hill^{-1} (11.37) was found in BRRI dhan34 × control at 85 DAT.

Leaf area index (LAI): The result showed that leaf area index increased with the increase in age of the plant up to 70 DAT and then declined (Table 1). It was found that BRRI dhan34 produced the highest leaf area index (5.431) at 70 DAT. The lowest leaf area index (4.907) was recorded at 70 DAT in BRRI dhan37. Different nutrient management had significant effect on leaf area index at all the DATs. It was observed that leaf area was the highest in 75% of recommended dose of inorganic fertilizers + 50% cowdung (Table 2). The leaf area index increased with the increasing days due to nutrient management at 30 DAT up to 70 DAT and then declined at 85 DAT probably due to leaf senescence at higher ages. The lowest leaf area index (3.163) was recorded in control at 85 DAT. The interaction effect between BRRI dhan34 and 75% of recommended dose of inorganic fertilizers + 50% cowdung produced the highest the leaf area index (6.4) at 70 DAT (Table 3). This might be resulting from potentiality of BRRI dhan34 and influence of nutrients. After 70 DAT leaf area index started to decline for all interactions. The lowest leaf area index was recorded (2.89) in the interaction effect of BRRI dhan38 and control at 85 DAT.

Table 3. Effect of interaction of variety and nutrient management on plant height and number of total tillers hill^{-1} at different DAT of aromatic fine rice

Interaction	Plant height (cm)					Number of total tillers hill^{-1}				
	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25DAT	40 DAT	55 DAT	70 DAT	85 DAT
$V_1 \times T_1$	43.60i-k	67.40i-k	89.60hi	97.33lm	110.5j-l	4.33h-k	6.93jk	11.07j-l	12.67l	12.03kl
$V_1 \times T_2$	47.33cd	76.27cd	95.87a-c	103.9de	115.8d-f	5.13b-d	8.60b	14.00a-c	15.07b-d	13.90de
$V_1 \times T_3$	44.73f-i	69.00g-j	91.87e-h	100.1h-k	111.7h-k	4.40g-j	7.20 h-j	11.53h-l	13.70i	12.43j
$V_1 \times T_4$	45.20e-g	69.67f-j	92.95d-g	102.3e-g	112.3g-j	4.47f-i	7.67e-g	11.80g-j	14.33g	13.70d-f
$V_1 \times T_5$	46.20de	72.27d-h	93.00d-g	103.2ef	114.3d-h	4.60f-h	7.67e-g	13.27c-e	14.53fg	13.70d-f
$V_1 \times T_6$	46.27de	73.53c-f	95.07b-d	103.4e	115.2d-g	5.00cd	7.87d-f	13.67 a-d	14.93b-e	13.83de
$V_1 \times T_7$	50.13a	92.0a	97.73a	111.6a	127.0a	6.47a	9.13a	14.33a	16.20a	15.60a
$V_1 \times T_8$	48.20 bc	77.33c	96.20ab	105.9c	120.1bc	5.20bc	8.67b	14.07ab	15.07b-d	14.37c
$V_2 \times T_1$	42.27 l	59.80n	81.20l	91.13n	101.7n	4.00l	6.40m	10.00m	12.10m	11.37m
$V_2 \times T_2$	45.33ef	70.53f-i	90.47gh	99.27i-l	114.0e-i	4.47f-i	7.80d-f	12.13f-h	14.73d-f	13.53e-g
$V_2 \times T_3$	42.73kl	62.53l-n	82.40l	92.07n	107.6lm	4.13jkl	6.80kl	10.80l	12.87kl	11.83l
$V_2 \times T_4$	43.73i-k	65.60j-l	86.87jk	96.67m	109.0k-m	4.20ij-l	7.07i-k	11.33i-l	13.23j	11.90l
$V_2 \times T_5$	44.07g-j	67.27i-k	87.53ij	98.07k-m	112.5f-j	4.33h-k	7.07i-k	11.33i-l	13.80i	12.57ij
$V_2 \times T_6$	45.07e-h	68.20h-j	88.13ij	98.87j-l	113.6fg-j	4.40g-j	7.53f-h	11.47h-l	14.33g	13.37fg
$V_2 \times T_7$	45.87ef	75.07c-e	97.33ab	105.7cd	120.6b	5.20bc	7.97de	13.53b-e	15.20bc	14.07cd
$V_2 \times T_8$	45.53ef	71.27e-i	92.80de-g	101.0g-i	117.2cde	4.93de	7.87d-f	12.80ef	14.73d-f	13.67d-f
$V_3 \times T_1$	43.40jk	60.07mn	85.20k	96.77m	106.4m	4.07kl	6.53lm	10.93kl	12.20m	11.77l
$V_3 \times T_2$	47.20 cd	72.47d-g	93.40d-f	101.9e-h	115.8d-f	4.73ef	7.87d-f	13.13de	14.90c-f	13.90de
$V_3 \times T_3$	44.00 h-j	30.80k-m	90.60gh	99.60 i-k	110.8ijk	4.20i-l	6.87j-l	11.33h-l	13.13jk	12.40jk
$V_3 \times T_4$	45.13e-h	66.00 j-l	91.00f-h	100.1h-k	112.1g-k	4.47f-i	7.33g-i	11.67g-k	13.90hi	12.83hi
$V_3 \times T_5$	45.80ef	67.33i-k	91.73e-h	100.3g-j	114.0e-i	4.53f-h	7.67e-g	12.07f-i	14.23gh	13.20gh
$V_3 \times T_6$	45.87ef	69.00g-j	91.80e-h	101.3f-i	114.0f-i	4.67fg	7.73ef	12.40fg	14.57e-g	13.53e-g
$V_3 \times T_7$	49.13ab	81.93b	97.40ab	108.2b	122.2b	5.27b	8.33bc	14.20ab	15.30b	14.77b
$V_3 \times T_8$	47.60c	77.00c	93.60c-e	105.5cd	117.4cd	5.00cd	8.13cd	13.23de	14.97b-d	13.93de

Sx	0.366	1.29	0.770	0.655	0.995	0.083	0.118	0.241	0.118	0.131
Level of sign.	*	**	**	**	*	**	*	*	*	**
CV (%)	1.39	3.15	1.46	1.25	1.51	3.08	2.69	3.39	1.45	1.71

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

Table 4. Effect of variety on total dry matter production $hill^{-1}$($g\ hill^{-1}$) and crop growth rate ($g\ m^{-2}day^{-1}$) at different DAT of aromatic fine rice

Varieties	Total dry matter production $hill^{-1}$($g\ hill^{-1}$)					Crop growth rate ($g\ m^{-2}day^{-1}$)			
	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25-40DAT	40-55 DAT	55 -70DAT	70-85 DAT
BRRI dhan34	3.514a	8.485a	18.49a	35.29a	49.47a	9.336a	18.61a	30.47a	25.55a
BRRI dhan37	2.881c	7.348c	16.73c	31.88c	45.56c	7.538c	16.07c	25.17c	23.44c
BRRI dhan38	3.220b	8.141b	17.98b	33.25b	46.71b	8.610b	16.97b	27.02b	24.57b
Sx	0.028	0.062	0.090	0.274	0.376	0.086	0.126	0.244	0.171
Level of sign.	**	**	**	**	**	**	**	**	**
CV (%)	4.30	3.85	2.50	4.02	3.9	4.99	3.60	4.35	3.41

Table 5. Effect of nutrient management on total dry matter production $hill^{-1}$($g\ hill^{-1}$) and crop growth rate ($g\ m^{-2}day^{-1}$) at DAT of aromatic fine rice

Nutrient management	Total dry matter production $hill^{-1}$($g\ hill^{-1}$)					Crop growth rate ($g\ m^{-2}day^{-1}$)			
	25DAT	40 DAT	55 DAT	70 DAT	85 DAT	25-40DAT	40-55 DAT	55 -70DAT	70-85 DAT
T_1	2.190g	6.423g	13.20h	23.41h	33.0h	5.57g	10.79g	15.50g	16.95h
T_2	3.643c	8.424bc	19.37c	39.10c	53.96c	9.03c	19.10c	33.28c	26.77c
T_3	2.590f	6.920f	14.81g	26.33g	39.73g	7.16f	14.66f	17.86f	22.06g
T_4	2.780e	7.507e	16.03f	27.62f	42.01f	7.43f	15.08f	21.56e	23.21f
T_5	2.870e	7.971d	17.56e	30.10e	44.23e	7.97e	16.74e	22.30e	24.52e
T_6	3.457d	8.241cd	18.79d	34.77d	48.19d	8.47d	18.45d	28.45d	25.40d
T_7	4.313a	9.788a	21.51a	43.95a	59.91a	12.11a	22.27a	41.65a	29.19a
T_8	3.797b	8.657b	20.60b	42.52b	56.93b	10.18b	20.63b	39.82b	28.05b
Sx	0.045	0.102	0.147	0.448	0.614	0.141	0.206	0.400	0.278
Level of sign.	**	**	**	**	**	**	**	**	**
CV (%)	4.30	3.85	2.50	4.02	3.9	4.99	3.60	4.35	3.41

Total dry matter (TDM) production: Results showed that initial increase of dry matter production was slow but it increased with the increase of time. It accelerated on later DATs and reached the peak at 85 DAT. BRRI dhan34 produced the highest dry matter $hill^{-1}$ (49.47 g $hill^{-1}$) followed by BRRI dhan38 (46.71 g $hill^{-1}$) and BRRI dhan37 (45.56 g $hill^{-1}$) at 85 DAT (Table 4). The highest total dry matter accumulation (59.91 g $hill^{-1}$) was observed at 85 DAT in treatment of 75% of recommended dose of inorganic fertilizers + 50% cowdung followed by treatment of 75% of recommended dose of inorganic fertilizers + 50% poultry manure and the lowest dry matter accumulation (33.0 g $hill^{-1}$) at the same DAT was observed in control (Table 5). Total dry matter increased progressively with the advancement of time due to interaction effect of varieties and nutrient management from 25 DAT up to 85 DAT (Table 6). At 85 DAT, the interaction effect between BRRI dhan34 and 75% recommended dose of inorganic fertilizers + 50% poultry manure produced the highest total dry matter (59.85 g $hill^{-1}$), which was statistically identical to BRRI dhan34 × 75% of recommended dose of inorganic fertilizers + 50% cowdung, BRRI dhan34 × 75% recommended dose of inorganic fertilizers + 50% poultry manure, BRRI dhan37 × 75% of recommended dose of inorganic fertilizers + 50% cowdung and BRRI dhan38 × 75% of recommended dose of inorganic fertilizers + 50% cowdung. The interaction effect of BRRI dhan34 × control produced the lowest total dry matter (34.15 g $hill^{-1}$) at 85 DAT, which was statistically identical to the interaction effects of BRRI dhan37 × control and BRRI dhan38 × control.

Crop growth rate (CGR): The crop growth rate initially started to increase with the advancement of time and reached to a peak at 55-70 DAT, then the crop growth rate declined at 70-85DAT (Table 4).The highest crop growth rate (30.47 g m^{-2} day^{-1}) was obtained in the variety BRRI dhan34 followed by BRRI dhan38 (27.02 g m^{-2} day^{-1}) at 55-70 DAT. The lowest crop growth rate (25.17 g m^{-2} day^{-1}) was recorded in case of BRRI dhan37at 55-70 DAT. 75% of recommended dose of inorganic fertilizers + 50% cowdung produced the highest crop growth rate (41.65 g m^{-2} day^{-1}) followed by 75% recommended dose of inorganic fertilizers + 50% poultry manure. The lowest crop growth rate (15.50 g m^{-2} day^{-1}) was recorded in control at 55-70 DAT (Table 5).The interaction effect of varieties and level of nutrient management on crop growth rate were significant at all DATs (Table 6). The highest crop growth rate (46.96 g m^{-2} day^{-1}) was observed in BRRI dhan34 × 75% of recommended dose of inorganic fertilizers + 50% cowdung at 55-70 DAT. The lowest crop growth rate (12.66 g m^{-2} day^{-1}) was observed due to BRRIdhan37 × control.

Table 6. Effect of interaction of variety and nutrient management on leaf area index (LAI), total dry matter production $hill^{-1}$ and crop growth rate ($g\ m^{-2}day^{-1}$) at different DAT of aromatic fine rice

Interaction	Leaf area index (LAI)					Total dry matter production $hill^{-1}$($g\ hill^{-1}$)					Crop growth rate ($g\ m^{-2}day^{-1}$)			
	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	25 DAT	40 DAT	55 DAT	70 DAT	85 DAT	25-40 DAT	40-55 DAT	55-70 DAT	70-85 DAT
V1×T1	1.170jk	1.780i	2.670j	3.870m	3.510k	2.47hi	6.47l	13.89ij	23.85j	34.15i	6.32i	12.65o	17.2k	19.45 k
V1×T2	1.470c	2.470c	3.850bc	5.750c	5.320b	3.91b	8.73c-e	19.90cd	43.66b	59.85a	9.77c	20.20de	37.58d	27.88bc
V1×T3	1.180jk	2.130ef	2.960i	5.030ij	4.450f-h	2.70gh	7.32i-k	15.55g	27.80gh	41.30fg	7.41gh	15.45mn	19.54ij	23.59hi
V1×T4	1.320e-h	2.150ef	3.300gh	5.200f-i	4.530e-g	3.01ef	8.17e-g	16.66f	28.62f-h	42.65fg	7.56fg	16.29k-m	23.23gh	23.93hi
V1×T5	1.390de	2.240de	3.450f-h	5.500de	4.820cd	3.15e	8.33d-g	18.14e	30.70f	47.10d	8.58de	17.28i-k	24.66g	25.64e-g

V1×T6	1.390c-e	2.310d	3.670c-e	5.520de	4.990c	3.81b	8.64c-e	19.69d	35.16e	49.64cd	8.62de	19.38e-g	30.81e	25.74d-g
V1×T7	1.670a	2.850a	4.260a	6.400a	5.990a	5.03a	11.06a	22.52a	46.32a	61.09a	15.27a	24.72a	46.96a	29.61a
V1×T8	1.550b	2.680b	4.150a	6.180b	5.360b	4.03b	9.16c	21.60b	46.23a	60.02a	11.15b	22.88b	43.76b	28.52abc
V2×T1	0.8700m	1.540j	2.340k	3.380n	2.890l	1.85j	6.34l	11.95k	22.94j	32.07i	4.25j	9.16q	12.66l	15.35l
V2×T2	1.300f-h	2.100fg	3.300h	5.260f-h	4.640d-f	3.20de	7.86g-i	18.44e	36.06de	50.49c	8.23ef	18.42gh	31.09e	26.01d-f
V2×T3	1.000l	1.770i	2.480k	4.470l	3.710k	2.46hi	6.64l	14.26h-j	24.37ij	37.64h	6.67hi	13.41o	16.25k	19.92k
V2×T4	1.180jk	1.930h	2.890i	4.910jk	4.160ij	2.62gh	6.86kl	14.89gh	26.22hi	41.54fg	7.34gh	13.46o	19.88ij	21.94j
V2×T5	1.210i-k	1.990gh	2.920i	4.950jk	4.240h-j	2.63gh	7.25jk	16.66f	29.06fg	41.81fg	7.43gh	16.10l-n	19.93ij	23.48hi
V2×T6	1.290f-h	2.090fg	2.930i	5.070h-j	4.360g-i	2.98ef	7.46h-j	18.14e	34.15e	46.49de	8.22ef	17.85h-j	27.05f	24.82f-h
V2×T7	1.550b	2.440c	3.890b	5.700cd	4.890cd	3.90b	8.44d-f	19.90d	42.44b	59.15a	9.73c	20.79cd	37.32d	28.79ab
V2×T8	1.370d-f	2.440c	3.660c-e	3.757m	4.650d-f	3.41cd	7.93f-h	19.56d	39.79c	55.30b	8.42de	19.38e-g	37.21d	27.23cd
V3×T1	0.9800l	1.730i	2.410k	3.757m	3.090l	2.25i	6.46l	13.76j	23.43j	32.88i	6.15i	10.55p	16.63k	16.04l
V3×T2	1.390de	2.440c	3.600d-f	5.350ef	4.820cd	3.82b	8.68c-e	19.78d	37.57d	51.53c	9.11cd	18.68f-h	31.16e	26.41de
V3×T3	1.150k	2.130ef	2.830ij	4.810k	4.090j	2.61gh	6.80kl	14.63hi	26.81gh	40.24gh	7.40gh	15.12n	17.79jk	22.66ij
V3×T4	1.240h-j	2.140ef	3.260h	5.100g-j	4.180ij	2.71gh	7.49h-j	16.54f	28.02gh	41.83fg	7.41gh	15.49mn	21.58hi	23.76hi
V3×T5	1.280g-i	2.180ef	3.260h	5.120g-j	4.650d-f	2.83fg	8.33d-g	17.87e	30.53f	43.78ef	7.92e-g	16.83j-l	22.32h	24.43gh
V3×T6	1.330e-g	2.190d-f	3.490e-g	5.300fg	4.730c-e	3.58c	8.62c-e	18.53e	35.00e	48.45cd	8.58de	18.12hi	27.50f	25.65efg
V3×T7	1.600ab	2.700b	3.910b	6.050b	5.450b	4.01b	9.86b	22.11ab	43.10b	59.48a	11.32b	21.31c	40.68c	29.16ab
V3×T8	1.450cd	2.520c	3.790b-d	5.540de	4.910cd	3.95b	8.88cd	20.63c	41.55bc	55.48b	10.98b	19.64ef	38.49d	28.41a-c
Sx	0.025	0.040	0.063	0.065	0.083	0.079	0.178	0.255	0.776	1.06	0.244	0.357	0.692	0.483
Level of sign.	*	*	**	**	*	**	*	*	**	*	**	**	**	*
CV (%)	3.31	3.25	3.29	2.19	3.19	4.30	3.85	2.50	4.02	3.9	4.99	3.60	4.35	3.41

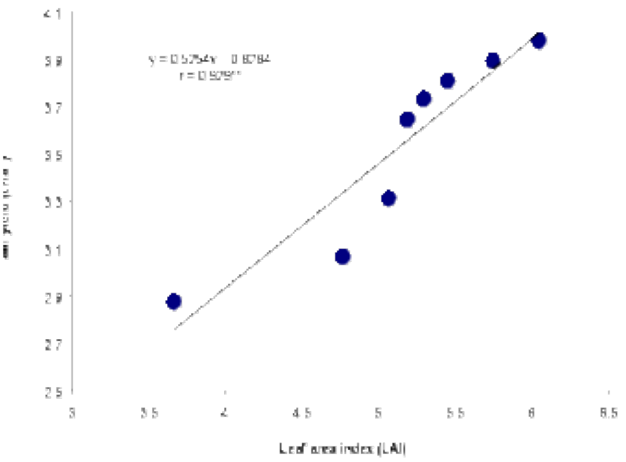

Fig. 1. Correlation between LAI and grain yield of aromatic fine rice

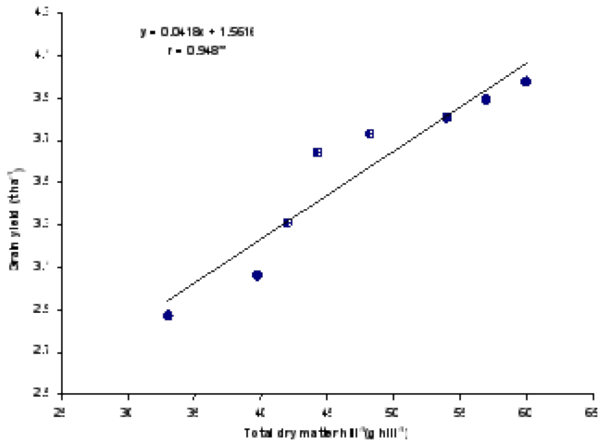

Fig. 2. Correlation between TDM and grain yield of aromatic fine rice

Relationship between leaf area index (LAI) at 70 DAT and grain yield of aromatic fine rice: Leaf Area Index (LAI), one of the most important vegetative characters, is closely related to the amount of photosynthetic surface available for photosynthesis in plant, is the basic process for higher grain yield. Experimental results revealed that grain yield showed significantly positive correlation (r = 0.929**) with leaf area index at 70 DAT (Fig. 1). This means an increase in leaf area index will result in the corresponding increase in the grain yield of aromatic fine rice. Similar trend of relationship between LAI and grain yield was also reported by Ray *et al*. (2015). This indicates that leaf area index might be the critical parameter in grain yield performance of aromatic fine rice.

Relationship between total dry matter production at 70 DAT and grain yield of aromatic fine rice: Total dry matter production is also an important parameter for increasing the yield of aromatic fine rice. Partitioning of dry matter in sink organs i.e. grains are responsible for the yield that we harvest from the rice plants. Experimental results revealed that grain yield showed significantly positive correlation (r = 0.948**) with total dry matter production at 70 DAT (Fig. 2). This indicates an increase in total dry matter production will result in the corresponding increase in the grain yield of aromatic fine rice, which signifies that total dry matter production also might be one of the critical parameters in yield performance of aromatic fine rice.

Considering the studied morpho-physiological parameters, it is evident that BRRI dhan34 and the nutrient management treatment of 75% of recommended dose of inorganic fertilizers + 50% cowdung as well as their interaction produced better growth parameters viz. LAI and TDM, which have strong positive relationship with grain yield in aromatic fine rice production.

References

BARC (Bangladesh Agricultural Research council). 1997. Fertilizer Recommendation Guide, BARC, Dhaka, Bangladesh.Field Crop Research. 93(2-2): 281-292.

BBS (Bangladesh Bureau of Statistics).2011. The Yearbook of Agricultural Statistics of Bangladesh. Statistics Div., Minis. Plan. Govt. peoples Repub., Bangladesh, Dhaka.p.54.

BRRI (Bangladesh Rice Research Institute). 2006. Annual Report for 2005. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh.

Chakravarthi, B.K. and Naravaneni, R.2006. SSR marker based DNA finger printing and diversity study in rice (*Oryza sativa* L). African J. Biotech. 5(9): 684-88.

FAO (Food and Agriculture Organization) 2004. FAO Indices of Food and Agricultural Production. Food Agric. Org., Italy. pp 16-19.

Gomez, K. A, and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. Int. Rice Res. Inst., John Wiley and Sons. New York, Chichester, Brisbane, Toronto, Singapore, p.680.

Hunt, R. 1978. The fitted curve in growth studies: Math and plant physiology (Eds. Rose, D.A. and Edwards. DAC). Acad. Press, London. pp. 283-289.

IRRI (International Rice Research Institute). 2004. Rice Today. Intl. Rice Res. Inst. 3(3) : 12-27.

Islam, SMM., Paul, SK., Sarkar MAR and Miah MAM. 2014. Growth of transplant *Aman* rice as influenced by weeding regime and integrated nutrient management. Bangladesh J. Prog. Sci. & Tec.:12(1): 049-054.

Kirttania, B., Sarkar, MAR, Paul Sk and Islam MS. 2013. Morpho-physiological attributes of transplant *Aman* rice as influenced by variety, age of tiller seedlings and nitrogen management. J. Agrofor. Environ., 7(2): 149-154.

Paul SK, Islam MS, Sarkar MAR, Das KR and Islam SMM.2016. impact of variety and level of nitrogen on the growth performance of HYV transplant aman rice. Prog. Agri.: 27: 32-38.

Radford, P.J. 1967. Growth analysis formulae. Their use and abuse. Carp. Sci. 7: 171-775.

Rahman, M. M. and Yakupitiyage, A. 2006. Use of fishpond sediment for sustainable aquaculture-agriculture farming. International Journal of Sustainable Development and Planning, 1: 192-202.

Ray S, Sarkar MAR, Paul Sk, Islam AKMM. Ansd Yeasmin S. 2015. Variation of growth, yield and protein content of transplant *Aman* rice by three agronomic practices. Agricultural and Biological Sciences Journal, 1(4):167-176.

Sritarapipat, T., Rakwatin, P., & Kasetkasem, T.2014. Automatic rice crop height measurement using a field server and digital image processing. Sensors, 14 (1), 900 – 926.