J Bangladesh Agril Univ 16(1): 5–11, 2018 *doi: 10.3329/jbau.v16i1.36472*

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

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau, www.banglajol.info/index.php/JBAU

Effect of age of seedlings at staggered transplanting and weed management on the growth and yield of aromatic *Boro* rice (cv. BRRI dhan50)

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ARTICLE INFO

Article history:
Received: 18 December 2017
Accepted: 06 April 2018

Keywords:
Age of seedlings, staggered transplanting, weed management, growth, yield

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Abstract

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during December 2015 to May 2016 to study the effect of age of seedlings at staggered transplanting and weed management on the growth and yield of aromatic *Boro* rice (cv. BRRI dhan50). The experiment comprised four seedling ages at staggered transplanting viz. 30, 45, 60 and 75-day old seedlings with five different weed management treatments viz. unweeded controls, two hand weeding at 20 and 35 DAT (days after transplanting), pre-emergence herbicide (Pendimethaiin, Panida 33EC) applied at 3 DAT + one hand weeding at 35 DAT, post-emergence herbicide (Penoxsulam, Granite 240 SC) applied at 12 DAT + one hand weeding at 35 DAT, pre-emergence herbicide (Panida 33 EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT. It was observed that the experiment was laid out in a randomized complete block design with three replications. The highest plant height and total dry matter hill^{-1} were recorded in 30-day old seedlings with pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT. Younger seedlings (30-day old) produced the highest number of total tillers hill^{-1} (11.08), effective tillers hill^{-1} (8.47), grains panicle^{-1} (80.76) and grain yield (3.94 t ha^{-1}) compared to aged seedlings at staggered transplanting. In case of weed management, pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT produced the highest number of effective tillers hill^{-1} (8.89), grains panicle^{-1} (81.66), 1000-grain weight (18.44 g), grain yield (4.47 t ha^{-1}) and straw yield (5.13 t ha^{-1}). Grain yield was reduced by 59.82% in unweeded control compared to pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT. In interaction, 30-day old seedlings combined with pre-emergence herbicide (Panida 33 EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT produced the highest effective tillers hill^{-1} (9.58), grains panicle^{-1} (89.47), 1000-grain weight (18.93g), grain yield (5.31 t ha^{-1}) and straw yield (5.75 t ha^{-1}). Therefore, 60-day old seedlings at staggered transplanting with pre-emergence herbicide (Panida 33EC) applied at 3DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT appears as the promising technique for aromatic *Boro* rice cultivation.

Introduction

Rice (*Oryza sativa* L.) is one of the major food crops of the world. The people in Bangladesh depend on rice as staple food. About 75.61% of cropped area of Bangladesh is used for rice production, with annual production of 34.71 million tons from 11.38 million ha of land (BBS, 2016a). Rice is grown here round the year as *Aus*, *Aman* and *Boro* crop according to change of seasonal condition. *Boro* rice covers an area of 4.77 million hectares with a production of 18.93 million tons (BBS, 2016a). The average yield of rice in Bangladesh is 3.04 t ha^{-1} (BBS, 2016b) and which is very much lower than world average. The rice economy in Bangladesh can be changed by improving production technologies of aromatic fine rice because of its high export potential, taste as well as better cooking qualities. The yield of aromatic rice is considerably low (1.5–2.0 t ha^{-1}) but its higher price and low cost of cultivation generated higher profit margins compared to other varieties grown in the area (Islam *et al.*, 1996). BRRI developed a modern aromatic *Boro* rice BRRI dhan50 suitable for *Boro* season. Its shape and size are similar to Basmoti rice. Demand for aromatic rice in recent years has increased to a great extent for both internal consumption and export (Singh *et al.*, 2000).

The use of seedlings from the same source transplanting at optimum date and thereafter at different dates are termed as staggered transplanting of rice seedlings having different ages. Sometimes transplanting of *Boro* rice is delayed due to unavailability of main field occupied by winter crops like vegetables, pulses and oil seed crops. In such cases, excess seedlings raised in the nursery bed which can be transplanted in the main field at a later date. The transplanting of healthy seedlings of optimum age ensures better rice yield. If the age of seedlings is increased than optimum, the seedlings produce fewer tillers due to reduced vegetative period thereby resulting in poor yield (Roy, 2015). When seedlings stay longer in nursery bed, primary tiller buds on the lower nodes of the main culm often degenerate. Primary tiller buds of 4th to 7th nodes are held inside when seedlings are planted at 7th leaf age (Motsuo and Hoshikawa, 1993). Seedling age at staggered transplanting is an important factor due to its tremendous influence on plant height, tiller production, panicle length, grains panicle^{-1} and other yield contributing characters (Islam and Ahmed, 1981).

As like as proper age of seedlings weed management also greatly influence grain yield of *Boro* rice. Severe weed infestation reduces the grain yield by 70.80% in *Aus* rice, 30–40% for transplanted *Aman* rice and 22–36% for modern *Boro* rice cultivation in Bangladesh (Sarkar *et al*., 2017a). Zannat *et al.* (2014) reported that grain yield reduced 28.16% due to weed infestation in aromatic rice Binadhan-9.The traditional method of weed control is hand weeding which is very much laborious and time consuming. Mechanical weeding and herbicides are the alternative to hand weeding. Herbicides are effective in controlling weeds alone or in combination with hand weeding (Ahmed *et al.,* 2005). Herbicides in combination with hand weeding would help to obtain higher crop yield with less efforts and cost (Sathyamoorthy *et al*., 2004). Weed competition at early growth stage can be eliminated through pre-emergence herbicides like Panida, Ronstar 25 EC and Rifit 50 EC and post emergence herbicides Granaite and 2, 4-D amine. This type of herbicides can be used in Bangladesh against mono and dicotyledonous weeds in rice fields. Replacement of traditional weeding in *Boro* rice by pre-emergence and post-emergence herbicides or herbicides in combination with hand weeding would help obtain higher rice yield. So, it is important to know not only seedling age but also weed management of *Boro* rice to augment the highest yield. Therefore, the present study was undertaken with a view to delineating the performance of aromatic *Boro* rice (cv. BRRI dhan50) with age of seedlings at staggered transplanting and weed management.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from December 2015 to May 2016. The experimental site is located at 24.75° N latitude and 90.50°E longitude at an altitude of 18 m. The site belongs to the non-calcareous dark grey floodplain soil under the Agro-ecological Zone Old Brahmaputra Floodplain (AEZ-9) (UNDP and FAO, 1988).The soil of the experimental field was silty loam in texture having pH 6.8 with 1.29 % organic matter. BRRI dhan50 (Banglamoti), a modern aromatic fine rice variety, was used as the test variety. The experiment comprised four ages of seedlings at staggered transplanting viz. 30, 45,60 and 75 days; five weed management viz. unweeded control, two hand weeding at 20 DAT and 35 DAT, pre-emergence herbicide (Pendimethaiin, Panida 33EC) @ 2.5 l ha^{-1}) applied at 3 DAT +one hand weeding at 35 DAT, post emergence herbicide (Penoxsulam, Granite 240 SC) @ 93.70 ml ha^{-1}) applied at 12 DAT + one hand weeding at 35 DAT, pre-emergence herbicide (Panida 33 EC @ 2.5 l ha^{-1}) applied at 3 DAT + post emergence herbicide (Granite 240 SC 93.70 ml ha^{-1})applied at 12 DAT. The experiment was laid out in a randomized complete block design with three replications. The size of unit plot was 4.0m × 2.5m. Seeds were sown in the nursery on 5 December with proper care. Seedlings were transplanted on 5 January, 20 January, 5 February and 20 February as per different ages of seedlings at staggered transplanting viz. 30, 45, 60 and 75 days, respectively in the well puddled plot. Transplanting was done by using two seedlings hill^{-1} with 25 cm ×15 cm spacing.

Data collection at vegetative stage

Five hills were randomly selected after 10 days of transplanting and marked with bamboo sticks in each plot excluding border rows to record the data on plant height and number of tillers hill^{-1} at 15-day intervals beginning 15 DAT up to 45 DAT. To determine the total dry matter, two plants were randomly uprooted from each plot excluding border rows and central 1 m^2 harvest area at 15, 30, and 45 DAT.

Data collection for weeds

Weed density was calculated species-wise at 65 DAT using 1 m^2 quadrate as per method described by Cruze *et al.* (1986) from three spots in each plot at random and converted to number m^{-2}. After determining the weed density, the weeds inside each quadrate were uprooted and cleaned. The collected weeds were dried in an electric oven for 72 hours at a temperature of 85 ± 5° C and their dry weights recorded by an electrical balance.

Data collection at harvest

At maturity (when 90 % of the grains became golden yellow in color) counted one square meter prefixed area from each plot was harvested to record grain and straw yields. Four hills were randomly selected from each plot (excluding boarder rows and central 1 m^2 harvest area) for recording data on crop characters and yield components. Transplanted seedlings of 30-day-old and 45-day-old were matured earlier and harvested on 7 May and 11 May 2016, respectively. Crops which were transplanted on 60 and 75-day old seedlings matured later and harvested on 16 May 2016. The harvested crop was threshed manually. The grain was cleaned and dried to a moisture content of 14 %. Straws were sun dried properly. Finally grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}. Harvest index was also calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield (grain yield + straw yield)}} \times 100$$

Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Vegetative characters

Plant height, number of tillers hill^{-1} and total dry matter hill^{-1} (TDM) were significantly influenced by seedling age at staggered transplanting (Table 1). Plant height gradually increased in course of time and reached maximum at final sampling date. At 45 DAT, the tallest plant (71.22 cm) was obtained when 60-day old seedlings were transplanted, which was statistically identical with that of 30-day old seedling while the shortest one (61.33 cm) was obtained in 75-day old seedlings. On the other hand, the highest number of tillers hill^{-1} (14.58) and total dry matter were recorded in 30-day old seedlings while the corresponding lowest values were recorded from 75-day old seedlings (Table 1).

Plant height, number of tillers hill^{-1} and total dry matter hill^{-1} (TDM) were significantly influenced by weed management (Table 2). All growth parameters were gradually increased in course of time and reached maximum at final sampling date. The highest values were obtained in pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT while the corresponding lowest values were obtained in unweeded plots. Weed severely competed with crop plants for nutrient, moisture and sunlight, subsequently reduced plant height, tiller number hill^{-1}and total dry matter (Table 2).

The interaction of seedling age at staggered transplanting and weed management exhibited significant influence on plant height, number of tillers hill^{-1} and total dry matter at all sampling dates (Table 3). At 45 DAT, the highest plant height (74.83 cm), number of tillers hill^{-1} (17.33) and total dry matter (24.59 g hill^{-1}) were recorded in the interaction of 45-day old seedlings with post emergence herbicide (Granite 240 SC) + 1 hand weeding at 35 DAT, 30-day old seedlings with pre-emergence herbicide (Panida 33 EC) + post emergence herbicide (Granite 240 SC) and 45-day old seedlings with pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT (Table 3).

Weed dry matter production

Weed dry matter at 65 DAT was significantly influenced by age of seedling at staggered transplanting (Table 1). The highest weed dry matter was recorded in 45-day old seedling and the lowest one was recorded in 30-day old seedling. Weed dry matter was significantly influenced by weed management (Table 2). The highest weed dry matter at 65 DAT was found in unweeded control. Other weed management practices produced lower weed dry matter, which were statistically identical (Table 2). Interaction between age of seedling and weed management showed significant effect on weed dry matter (Table 3). The highest weed dry matter was found in 60-day old seedling with unweeded control and the lowest one was found in 30-day old seedling with post-emergence herbicide (Granite 240 SC) applied at 12 DAT+ one hand weeding at 35 DAT.

Crop characters, yield components and yield

Crop characters, yield components and yield were significantly affected by seedling age at staggered transplanting except sterile spikelets panicle^{-1} and 1000-grain weight (Table 4). The highest plant height (84.75 cm) was obtained in 45-day old seedlings, which was at par with 30-day old seedlings. The highest number of total tillers hill^{-1} (11.70) was found in 60-day old seedlings, which was statistically identical with 30-day old seedlings. The highest number of effective tillers hill^{-1} (8.47) was found in 30-day old seedlings which was as good as 45- and 60-day old seedlings. Number of total tillers hill^{-1} exhibited a trend of decrease with the increase in seedling age. Younger seedlings produced more tillers than the older ones due to quick regeneration of seedlings and plant vigour. Similar results were also reported by Haque (2002). The longest panicle (19.83 cm), grains panicle^{-1} (80.76), grain yield (3.94 t ha^{-1}) and straw yield (4.70 t ha^{-1}) were obtained from 30-day old seedlings. Similar, trend was reported by Luna *et al.* (2017). Number of grains panicle^{-1} exhibited a trend of decrease with the increase in seedling age. This finding is in conformity with that of Razzaque *et al.* (2000). Younger seedlings produced more grains panicle^{-1} than older ones due to longer vegetative period when spikelets were formed in the spike before emergence of the panicles. All crop characters, yield components and grain and straw yields showed the lowest values in 75-day old seedlings because of their long stay in the nursery bed, which resulted in basal node formation in the seedlings. So the seedlings more time to get established in the main field and subsequently reduced the number of effective tillers hill^{-1} compared to younger seedling.

Crop characters, yield components and yield were significantly influenced by weed management except 1000-grain weight (Table 5). The highest plant height (85.60 cm)and the longest panicle (20.26 cm) were recorded in post emergence herbicide (Granite 240 SC) + 1 hand weeding at 35 DAT and the lowest values were obtained in unweeded plots. The highest number of effective tillers hill^{-1} (8.89) and grains panicle^{-1} (81.66) were obtained in pre-emergence herbicide (Panida 33 EC) + post emergence herbicide (Granite 240 SC) while the highest number of sterile spikelets (17.89) were found in unweeded plots. Similar trend was reported by Sarkar *et al.* (2017 b). The highest grain yield (4.47 t ha^{-1}), straw yield (5.13 t ha^{-1}) and harvest index (46.43%) were obtained from pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT while corresponding lowest values were recorded from in unweeded control plots (Table 5). Unweeded control reduced 59.82% grain yield pre- emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT. There are evidences that weed reduced 22-36% grain yield in *Boro* rice (Mamun, 1990) and 28.16% in aromatic fine rice (Zannat *et al.*, 2014).

Crop characters, yield components and yield were significantly influenced by the interaction between seedling age and weed management except plant height and 1000-grain weight (Table 6). The highest number of total tillers $hill^{-1}$(17.11) was found in 60-day old seedling with two hand weeding at 20 DAT and 35 DAT while the highest number of effective $tillers^{-1}$ (10.50) was found in 30-day old seedlings with pre-emergence herbicide (Panida 33EC) + one hand weeding at 35 DAT. These effective tillers were at par with 30-day old seedling with pre-emergence herbicide (Panida 33 EC) + post emergence herbicide (Granite 240 SC) and post emergence herbicide (Granite 240 SC) +one hand weeding at 35 DAT. The highest number of grains panicle (89.47), grain yield (5.31 t ha^{-1}) and straw yield (5.75 t ha^{-1}) were found in the interaction of 30-day old seedlings with pre-emergence herbicide (Panida 33EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT. The lowest grain and straw yields and harvest index were recorded in 30-day old seedling with unweeded control (Table 6).

Table 1. Effect of age of seedlings at staggered transplanting on plant height, number of tillers $hill^{-1}$, total dry matter (TDM) and weed dry matter

Age of seedlings (days)	Plant height (cm)			Number of tillers $hill^{-1}$			Total dry matter $hill^{-1}$ (TDM)			Weed dry matter (g m^{-2}) at 65 DAT
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	
30	36.35a	48.24a	70.29a	7.75a	9.22a	14.53a	4.02a	14.27a	16.80a	5.26c
45	32.37b	51.92a	64.78b	5.42b	9.34a	13.45b	2.31b	10.77b	14.90b	8.69a
60	30.45bc	49.14a	71.22a	4.33c	9.47a	10.42c	1.67c	7.07c	14.65b	7.87b
75	28.71c	39.13b	61.33c	4.63c	5.85b	8.37d	0.63d	2.82d	11.90c	5.71c
Level of sig.	**	**	**	**	**	**	**	**	**	**
CV (%)	10.50	12.49	3.39	12.12	12.21	9.44	10.51	10.87	8.80	13.48

In a column figures with same letter 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 and NS = Not significant

Table 2. Effect of age of weed management on plant height, number of tillers $hill^{-1}$, total dry matter (TDM) and weed dry matter

Weed management	Plant height (cm)			Number of tillers $hill^{-1}$			TDM			Weed dry matter (g m^{-2}) at 65 DAT
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	
W_0	29.28b	45.63	65.44	3.96c	6.15c	7.50d	1.95b	6.45e	8.68d	15.78a
W_1	31.67ab	44.50	65.33	5.29b	8.55b	10.85c	2.04b	7.86d	13.80c	4.54b
W_2	34.03a	48.48	68.52	5.86b	8.76b	12.98b	2.47a	8.96c	14.96b	5.33b
W_3	30.90b	48.38	68.02	5.79b	8.94b	12.79b	1.97b	9.25b	14.91b	4.13b
W_4	33.98a	48.56	67.21	6.77a	9.95a	14.33a	2.38a	11.16a	20.46a	4.63b
Level of sig.	**	NS	NS	**	**	**	**	**	**	**
CV (%)	10.50	12.49	3.39	12.12	12.21	9.44	10.51	10.87	8.80	13.48

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

** = Significant at 1% level of probability, NS = Not significant

W_0 : Unweeded, W_1 : Two Hand weeding at 20 DAT and 35 DAT, W_2 : Pre-emergence herbicide (Panida 33EC) applied at 3 DAT+ one hand weeding at 35 DAT, W_3 : Post emergence herbicide (Granite 240 SC) applied at 12 DAT + one hand weeding at 35 DAT, W_4 : Pre-emergence herbicide (Panida 33 EC) applied at 3 DAT+ post-emergence herbicide (Granite 240 SC) applied at 12 DAT

Table 3. Effect of interaction between of age of seedlings at staggered transplanting and weed management on plant height, number of tillers hill^{-1}, total dry matter (TDM) and weed dry matter

Interaction (Age of seedling × Weed management)	Plant height(cm)			Number of tillers hill^{-1}			TDM			Weed dry matter (g m^{-2}) at 65 DAT
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	
$A_1 \times W_0$	35.67	47.33	74.27a	3.92fg	7.08f-i	11.17d	3.46cd	9.99de	7.88jk	11.80c
$A_1 \times W_1$	34.42	41.43	65.67bcd	6.75cd	8.67efg	14.17c	3.62c	13.50c	19.11b	6.09f
$A_1 \times W_2$	37.83	53.58	72.42ab	7.17bc	7.92e-i	14.75c	4.12b	15.61b	16.20de	3.40ghi
$A_1 \times W_3$	34.92	51.25	70.25abc	8.83b	9.67cde	15.58abc	3.78bc	14.87bc	16.48de	1.60j
$A_1 \times W_4$	38.92	47.58	68.83abc	12.08a	12.75a	17.00ab	5.14a	17.40a	24.34a	3.41ghi
$A_2 \times W_0$	28.50	50.83	59.83de	4.42efg	6.67hi	7.50fg	2.14e	8.41ef	11.05hi	14.67b
$A_2 \times W_1$	31.33	49.00	62.83cd	5.58c-g	8.45e-h	10.08de	1.69f	8.22f	14.64d-g	6.38f
$A_2 \times W_2$	34.75	53.75	69.83abc	5.42c-g	10.69bcd	17.33a	3.10d	10.44d	14.61d-g	4.95fg
$A_2 \times W_3$	32.08	52.17	64.17bcd	5.83c-f	9.25cde	15.17bc	2.47e	11.24d	15.39def	9.50de
$A_2 \times W_4$	35.17	53.83	67.25a-d	5.83c-f	11.65abc	17.17a	2.13e	15.55b	18.80bc	7.95e
$A_3 \times W_0$	26.37	49.92	74.42a	3.67g	6.83ghi	6.17gh	1.67f	4.75gh	7.19k	26.65a
$A_3 \times W_1$	30.58	47.38	68.33abc	4.33efg	11.00abc	11.42d	2.13e	6.12g	11.47hi	4.01gh
$A_3 \times W_2$	34.33	46.25	68.42abc	4.67efg	9.83b-e	11.50d	2.13e	6.33g	16.70cd	4.08gh
$A_3 \times W_3$	28.42	49.50	74.83a	4.17efg	10.83bc	11.25d	0.85g	8.33ef	13.28fgh	2.28ij
$A_3 \times W_4$	32.57	52.67	70.08abc	4.83d-g	8.83def	11.75d	1.59f	9.82def	24.59a	2.33ij
$A_4 \times W_0$	26.58	34.42	53.25e	3.83fg	4.00j	5.17h	0.53g	2.65i	8.60jk	10.01d
$A_4 \times W_1$	30.33	40.17	64.48bcd	4.50efg	6.08i	7.75fg	0.73g	3.59hi	9.98ij	1.68j
A4 × W_2	29.20	40.33	63.42cd	6.17cde	6.58hi	8.33ef	0.51g	3.43hi	12.32gh	8.90de
$A_4 \times W_3$	28.20	40.58	62.83cd	4.33efg	6.00i	9.17ef	0.76g	2.54i	14.48d-g	3.14hij
$A_4 \times W_4$	29.25	40.17	62.67cd	4.33efg	6.58hi	11.42d	0.65g	1.87i	14.10efg	4.84fgh
Level of sig.	**	NS	*	**	**	**	**	**	**	**
CV (%)	10.50	12.49	3.39	12.12	12.21	9.44	10.51	10.87	8.80	13.48

In a column figures with same letter 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 = Not significant

A_1: 30-day, A_2: 45-day, A_3: 60-day, and A_4: 75-day old seedling

W_0 :Unweeded, W_1 : Two hand weeding at 20 DAT and 35 DAT, W_2 : Pre-emergence herbicide (Panida 33EC) applied at 3 DAT + one hand weeding at 35 DAT,W3$_1$:Post emergence herbicide (Granite 240 SC) applied at 12 DAT + one hand weeding at 35 DAT , W_4 : Pre-emergence herbicide (Panida 33 EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT

Table 4. Effect of age of seedlings at staggered transplanting on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Age of seedling (day)	Plant height	Number. of total tillers hill^{-1}	Number. of 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})	Straw yield (t ha^{-1})	Harvest index (%)
30	83.15a	11.08ab	8.47a	19.83a	80.76a	16.95	18.09	3.94a	4.70a	43.31
45	84.75a	9.87c	7.65ab	19.84a	78.59b	16.27	17.98	3.60b	4.88a	42.20
60	82.80a	11.70a	7.58ab	18.42b	72.06c	15.26	18.17	3.26c	4.38a	41.77
75	71.82b	10.23b	6.98b	18.84b	62.52d	15.50	18.03	2.82d	3.60b	43.64
Level of sig.	**	**	**	**	**	NS	NS	**	**	NS
CV (%)	4.25	10.00	10.80	7.04	13.91	15.33	3.97	11.79	11.40	10.44
Level of sig.	**	**	**	**	**	NS	NS	**	**	NS

In a column, figures with same letter 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 = Not significant

Table 5. Effect of weed management on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Weed management	Plant height (cm)	Number. of total tillers hill^{-1}	Number. of 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})	Grain yield loss (%)	Straw yield (t ha^{-1})	Harvest index (%)
W_0	78.04b	7.40b	5.38c	17.46b	67.88c	17.89a	18.25	1.82e	59.82	3.20d	36.10c
W_1	79.33b	11.27a	7.73b	19.34a	67.37c	16.78ab	17.97	2.94d	34.22	4.29c	40.98b
W_2	78.35b	11.83a	8.29ab	18.96a	71.24bc	16.24ab	17.88	3.72c	16.77	4.52bc	44.60ab
W_3	85.60a	11.75a	8.06b	20.26a	79.28ab	15.13bc	17.78	4.08b	8.72	4.82ab	45.55a
W_4	81.81ab	11.35a	8.89a	20.16a	81.66a	13.94c	18.44	4.47a	0.00	5.13a	46.43a
Level of sig.	*	**	**	**	**	**	NS	**	-	**	**
CV (%)	4.25	10.00	10.80	7.04	13.91	15.33	3.97	11.79	-	11.40	10.44

In a column figures with same letter 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 = Not significant

W_0 : Unweeded, W_1 : Two Hand weeding at 20 DAT and 35 DAT, W_2 : Pre-emergence herbicide (Panida 33EC) + one hand weeding at 35 DAT, W_3 : Post emergence herbicide (Granite 240 SC) + one hand weeding at 35 DAT, W_4 : Pre-emergence herbicide (Panida 33 EC) applied at 3 DAT+ by post emergence herbicide (Granite 240 SC) applied at 12 DAT

Table 6. Effect of interaction between age of seedlings at staggered transplanting and weed management on crop characters, yield components and yield of aromatic *Boro* rice (cv. BRRI dhan50)

Age of seedlings × weed management	Plant height	Number of tillers hill^{-1}	Number of 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})	Straw yield (t ha^{-1})	Harvest index (%)
$A_1 \times W_0$	78.00	6.83h	5.25ij	17.93bc	63.12c-f	17.99	18.18	1.04k	2.81h	27.76e
$A_1 \times W_1$	84.25	10.25def	7.75c-f	20.86ab	84.63ab	17.87	17.71	3.49efg	4.76bcd	42.49a-d
$A_1 \times W_2$	84.75	13.92ab	10.50a	18.81abc	80.57a-d	18.17	18.33	5.04ab	5.12abc	49.57a
$A_1 \times W_3$	88.83	11.67cd	9.25abc	21.19a	86.03ab	17.73	17.68	4.80abc	5.05abc	48.71ab
$A_1 \times W_4$	79.92	12.75abc	9.58ab	20.38abc	89.47a	12.99	18.53	5.31a	5.75a	48.03ab
$A_2 \times W_0$	82.75	7.08h	5.58hij	19.40abc	79.93a-d	17.76	18.18	2.48ij	3.71e-h	40.16bcd
$A_2 \times W_1$	85.33	9.50efg	6.67f-i	19.25abc	73.38a-e	17.40	17.93	3.46efg	5.42ab	38.92cd
$A_2 \times W_2$	85.58	10.42def	8.25b-e	19.91abc	78.84a-e	15.86	17.56	4.24cd	5.36ab	44.20abc
$A_2 \times W_3$	85.08	10.42def	8.33b-e	20.17abc	78.74a-e	14.13	17.61	3.67def	5.02abc	42.11a-d
$A_2 \times W_4$	85.00	11.92cd	9.42ab	20.45abc	82.06abc	16.17	18.62	4.14cde	4.92a-d	45.62abc
$A_3 \times W_0$	75.83	7.50h	4.50j	13.81d	60.96def	18.35	18.34	1.77j	3.49fgh	35.13de
$A_3 \times W_1$	77.25	14.17a	9.00a-d	19.39abc	59.30ef	14.43	18.46	2.45ij	4.04d-g	38.03cd
$A_3 \times W_2$	85.50	11.92cd	7.33efg	19.36abc	75.49a-e	15.17	17.94	2.84ghi	4.30c-f	39.92bcd
$A_3 \times W_3$	86.08	12.83abc	7.83c-f	19.15abc	74.00a-e	16.29	17.70	4.53bc	4.64b-e	49.56a
$A_3 \times W_4$	89.33	12.08bcd	9.22abc	20.40abc	90.53a	12.06	18.41	4.71abc	5.46ab	46.24abc
$A_4 \times W_0$	75.58	8.17gh	6.17ghi	18.70abc	67.49b-e	17.45	18.31	1.97j	2.81h	41.36a-d
$A_4 \times W_1$	70.50	11.17cde	7.50d-g	17.84bc	52.15f	17.43	17.79	2.36ij	2.92h	44.48abc
$A_4 \times W_2$	57.58	11.08cde	7.08efg	17.76c	50.07f	15.76	17.70	2.73hi	3.31gh	44.71abc
$A_4 \times W_3$	82.42	12.08bcd	6.83e-h	20.54abc	78.34a-e	12.36	18.15	3.30fgh	4.57b-e	41.82a-d
$A_4 \times W_4$	73.00	8.67fgh	7.33efg	19.39abc	64.58c-f	14.52	18.18	3.72def	4.38c-f	45.81abc
Level of sig.	NS	**	**	*	*	NS	NS	**	**	**
CV (%)	4.25	10.00	10.80	7.04	13.91	15.33	3.97	11.79	11.40	10.44

In a column figures with same letter 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 = Not significant

A_1: 30-day, A_2:45-day, A_3: 60-day and A_4: 75-day old seedling, W_0 : Unweeded control, W_1 : Two hand weeding at 20 DAT and 35 DAT, W_2 : Pre-emergence herbicide (Panida 33EC) applied at 3 DAT + one hand weeding at 35 DAT, W_3:Post emergence herbicide (Granite 240 SC) applied at 12 DAT + one hand weeding at 35 DAT , W_4 : Pre-emergence herbicide (Panida 33 EC) applied at 3 DAT + post emergence herbicide (Granite 240 SC) applied at 12 DAT

Relationship between weed dry matter production at 65 DAT and grain yield of aromatic *Boro* rice (cv. BRRI dhan50)

More or less maximum weed infestation was found at 65 DAT, therefore, this stage (65 DAT) was considered to find out a functional relationship between weed dry matter production and grain yield. The relationship of weed dry matter production at 65 DAT and grain yield was determined by using respective weed management treatment. It was observed that there was a negative relationship between weed dry matter production and grain yield of BRRI dhan50 (Figure 1). The functional relationship was significant at $p \leq 0.01$. The functional relationship can be determined by the regression equation $Y = -0.1982x + 4.81$ ($R^2 = 0.8866$). The functional relationship indicates that 89% of the variation in grain yield could be explained from the variation in weed dry matter production at 65 DAT. On an average, grain yield would be decreased at the rate of 0.1 t ha with an increase in one unit of weed dry matter production. This finding is in agreement with that of Hossain (2012) who reported that 57% of *Boro* rice (cv. BRRI dhan29) yield could be explained by the functional relationship of weed dry matter production at 45 DAT while Islam *et al.* (2015) reported that 80% of the variation in grain yield could be explained from the variation in weed dry matter production at 60 DAT in BRRI dhan49.

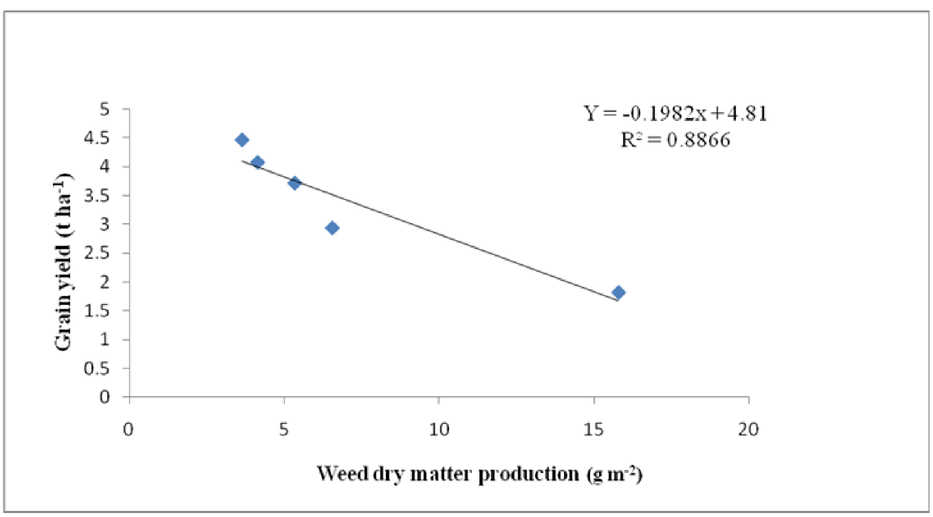

Figure 1. Relationship between weed dry matter production and grain yield of aromatic *Boro* rice (cv. BRRI dhan50)

Conclusion

From this study it can be concluded that 30-day old seedling with pre-emergence herbicide (Panida 33 EC) applied at 3 DAT + post-emergence herbicide (Granite 240 SC) applied at 12 DAT is the best one for grain yield of aromatic *Boro* rice cv. BRRI dhan50 under normal transplanted condition. In case of staggered transplanting, 60-day old seedlings in combination with pre-emergence herbicide (Panida 33EC @2.5 l ha^{-1}) applied at 3DAT + post-emergence herbicide (Granite 240 SC 93.70 ml ha^{-1}) applied at 12 DAT appears as the promising technique for aromatic *Boro* rice cultivation which is as good as 30-day old seedlings with the same weed management practice. The transplanting of *Boro* rice can further be delayed up to 75-day old seedlings (Transplanting on 20 February) with an appreciable grain yield of 3.72 t ha^{-1}where there is no possibility of getting younger seedlings.

Acknowledgement

The financial assistance of the Ministry of Science and Technology, Govt. of the People's Republic of Bangladesh to carry out the research work is thankfully acknowledged.

References

Ahmed, G.J.U., Bhuiyan, M.K.A., Riches, C.R., Mortimer, M. and Jhonson, D. 2005. Farmer's participatory studies of integrated weed management system for intensified low land. Proceeding of the 8th Biennial Agronomy Convention, Bangladesh Agron. J. 23: 31–32.

BBS (Bangladesh Bureau of Statistics).2016a. Statistical Year Book of Bangladesh, Bur. Stat., Stat. Div., Min. Plan., Govt. People's Repub. Bangladesh, Dhaka. pp. 50–68.

BBS (Bangladesh Bureau of Statistics).2016b. Estimates of *Aman* Rice (Husked), 2014–15, at the Website: www.bbs. gov.bd.

Cruz, E.D., Moody, K. and Ramos, M.B.D. 1986. Reducing variability sampling weeds in upland rice (*Oryza sativa*). Philipp. J. Weed Sci. 13: 56–59.

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. 680p.

Haque, D.E. 2002. Effect of Madagascar Technique of younger seedling and wider spacing on growth and yield of *Boro* rice. M.S. Thesis, Dept. Agron., Bangladesh Agril. Univ. Mymensingh. pp. 28–71.

Hossain, M.Z. 2012. Maximizing yield of transplant Aman rice and *Boro* rice through adoption of system of rice intensification. Ph. D. Thesis, Dept. Agron. Bangladesh Agril. Univ., Mymensingh. pp. 645–51.

Islam, S.M.M., Paul, S.K. and Sarkar, M.A.R. 2015.Effect of weeding regime and integrated nutrient management on yield contributing characters and yield of BRRI dhan49. J. Crop and Weed, 11: 193–197.

Islam, M., Rafiqul, B.A.A., Mustafi, S. and Hossain, M. 1996. Socio-economic aspects of fine quality rice cultivation in Simulation of Yield Losses Caused by Rice Diseases, Insects, and Weeds in Tropical Asia. IRRI Discussion Paper Series No. 34. pp. 18–20.

Islam, M.S.A. and Ahmed, J.U. 1981. Effect of age of seedlings on yield of the transplant aman rice cultivars. Bangladesh J. Agril. Sci. 892:175–179.

Luna, M.A., Sarkar, M.A.R., Uddin, M.R. and Sarker, U.K. 2017. Effect of age of seedlings at staggered planting and nitrogen rate on the growth and yield of transplant *Aman* rice. J. Bangladesh Agril. Univ. 15(1): 21–25.

Mamun, A.A. 1990. Weeds and their control: A review of weed research in Bangladesh. Agricultural and Rural Development in Bangladesh. Japan Intl. Co-operation Agency, Dhaka, Bangladesh. JSARD. 19: 45–72.

Matsuo T. and Hoshikawa, K. 1993: Science of rice plant: Morphology. Food and Agriculture Policy Research Center, Tokyo, p. 686.

Razzaque, A.S.M.A., Islam, N., Karim, M.M. and Salim, M. 2000. Effect of NP fertilizers and seedling age in reducing field duration of transplant *Aman* rice. Progress. Agric. 11(1&2): 111–116.

Roy, A. 2015. Effect of age of seedlings at staggered planting and nutrient management on the growth and yield of aromatic fine rice (cv. BRRI dhan38) M.S. Thesis, Dept. Agron. Bangladesh Agril. Univ., Mymensingh. p 2.

Sarkar, M.A.R., Paul, S.K. and Paul, U. 2017a. Effect of plant nutrient and weed management in direct wet seeded *Boro* rice. Progress. Agric. 27 (4): 466–472.

Sarkar, M.A.R., Paul, S.K. and Paul, U. 2017b. Effect of water and weed management in *Boro* rice (cv. BRRI dhan28) in Bangladesh. *Archives of Agriculture and Environmental Science.* 2(4): 325–329.

Sathyamoorthy, N.K., Mahendran, S., Babu, R. and Ragavan, T. 2004. Effect of integrated weed management practices on total weed dry weight, nutrient removal of weeds in rice-rice wet seedbed system. J. Agron. 3(4): 263–267.

Singh, R.K., Singh, U.S. and Khush, G.S. 2000. Aromatic Rices.Oxford and IBH Publishing Co. Ltd. New Delhi. p.279.

UNDP and FAO (United Nations Development Programme and Food and Agriculture Organization). 1988. Land Resources Appriasal of Bangladesh for Agricultural Development Rep. 2. Agroecological Regions of Bangladesh. BARC/ UNDP, New Airport Rode, Farmgate, Dhaka-1207. pp. 212–221.

Zannat, S.T., Paul, S.K. and Salam, M.A. 2014. Effect of weeding regime and nitrogen management on the performance of transplant aromatic *Aman* rice (cv. Binadhan-9). Bangladesh J. Seed Science & Technology, 18 (1 & 2): 29–34.