Original Research Article

Agronomic Performances of Rice Varieties at Different Transplanting Ages

ABSTRACT

A field experiment was carried out during the period from November 2012 to May 2013 in Agro-ecological Zone 20 (Eastern Surma-Kushiyara Floodplain) in country? to observe the varietal performances of high yielding and local varieties of Boro rice. Four varieties viz. BRRI dhan28, BRRI dhan29, Khoiaboro and Begunbichi, and transplanting of three seedling ages viz. 15, 20 and 25 days old were included as treatments in the experiment. The experiment was laid out in a factorial ~~RCBD (R~~randomized c~~C~~omplete b~~B~~lock d~~D~~esign (RCBD) with three replications. The results revealed that BRRI dhan29 produced significantly highest grain yield (6.25 t ha^{-1}) attributed by the higher number of effective tillers $hill^{-1}$ ~~,~~(value?), ~~-~~grains $panicle^{-1}$,(value?), and 1000-grain weight (value?). BRRI dhan28 produced the second highest grain yield (5.37 t ha^{-1}) while the local variety Begunbichi produced the lowest grain yield (2.26 t ha^{-1}) in spite of its highest number of grains $panicle^{-1}$,(value?), ~~-~~because of its small~~-~~sized (value?) grain. Total number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, unfilled spikelets $panicle^{-1}$, grain and straw yield varied significantly but other characters did not among different ages of seedlings. The highest grain yield of 4.49 t ha^{-1} was obtained from planting 25~~-~~day~~s~~ ~~-~~old seedlings ascribed to higher number of grains $panicle^{-1}$ ~~mainly~~. Grain yield of 4.23 t ha^{-1} was obtained from planting 20 ~~-~~day~~s~~ ~~-~~old seedlings which was statistically similar to that of planting 25 and 15 ~~-~~day~~s~~ ~~-~~old seedlings. Interaction of variety and seedling age produced significant effect on ~~most of the~~ characters ~~except plant height, number of non effective tillers hill^{-1}, length of panicle and grain yield~~. This ~~indicated~~ indicates that all varieties require planting 25~~-~~day~~s~~ ~~-~~old seedlings ~~for~~ to obtain higher grain yield. Cost and return analysis showed that BRRI dhan29 gave maximum gross return, net return, and Benefit Cost Ratio of US$ 1665.00 ha^{-1}, US$ 699.28 and 1.72, respectively with planting 25~~-~~day~~s~~ ~~-~~old seedlings. Local variety Begunbichi showed more profitability than BRRI dhan28 and local Khoiaboro varieties.

Key words: Boro rice, Variety, Seedling age, Yield

1. INTRODUCTION

Rice is the staple food of about 149.69 million people of Bangladesh and it is being grown in about 75% of the total cropped area and more than 80% of the total irrigated area [16]. Almost all the farm families

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of 13 million grow rice in the country. It provides nearly 40% of national employment (48% of rural employment), about 70-76% of total calorie supply and 66% of protein intakes of an average person in the country [16, 10]. Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh [17]. Thus, rice plays a vital role in the livelihood of the Bangladeshi people. Rice production needs to be increased more as the population of Bangladesh is still growing by two millions in every year and may increase by another 30 millions over the next 20 years. There are less possibilities of bringing more lands under cultivation of rice; much of the additional rice requirement will have to be met by increasing the average yield from the existing land. Although rice is grown on large area in Bangladesh, its average yield is still far below the levels attained in other rice producing countries in spite of having many high yielding varieties. The average yield in Bangladesh is about 2.74 t ha^{-1} as compared to Japan (5.93 t ha^{-1}) and Korea (6.12 t ha^{-1}) [19]. To combat the situation it requires adoption of modern technologies such as better management package, high yielding cultivars of both inbred and hybrid, and higher input use [42]. There are several reasons behind this but one of the most important reasons is that the seedling age is not managed properly to get vigorous seedlings for uniform stand and better bush establishment. Among the various factors that influence rice productivity, seedling age has tremendous effect on plant height, tiller production, panicle length, grain formation and other yield attributing characters [1]. Younger seedlings may not be able to withstand transplanting shock whereas too old seedlings may not be able to produce its yield potential to the peak. Transplanting seedlings in proper age can provide appropriate ground for achieving potential production by reducing the death of tillers. Chopra *et al. (*2002) evaluated the yield and quality of seeds of the rice cv. Pusa 44 by transplanting seedlings at 25, 35, 45, 55, and 65 days [7]. They found that transplanting seedlings at 35 days resulted greater number of panicles $hill^{-1}$, panicle length, 1000 seed weight and seed yield than 55 to 65-day old seedlings. Farmers transplant seedlings at different ages but more often with those of at 25 to 50 days older in lowland rice [9, 41, 35]. Many researchers reported that grain yield increased by transplanting younger seedlings of 25 days [36, 2, 26, 39]. On the other hand some studies exposed that grain yield was not affected by transplanting even 30-60 days old seedlings [6]. Recent studies on the System of Rice Intensification (SRI) also showed that yield and yield components of rice might be increased by transplanting seedlings as younger as 14 days as compared to older seedlings of 21-23 days [22]. McHugh (2002) also observed in Madagascar that 8 to 15 days old seedlings transplanted at 25 hills m^2 produced the highest yields [24]. Bangladesh Rice Research Institute (BRRI) has recommended to

decide seedling age of rice for transplanting according to growing season. BRRI (1991; 1992) recommended for transplanting 20-30 days old seedlings in Aus season, 20-35 days old seedlings in T. Aman season and 40-45 days old seedlings in Boro season [4, 5]. It is generally seen that Researchers' recommendations are not following by farmers [17] and it has been reported that farmers even use 80 days old seedlings of Boro rice for transplanting [18]. In Bangladesh, transplantation of younger seedlings ~~transplantation~~ in Boro season is very difficult and it is labour~~ ~~intensive because of stunted growth of seedlings due to cold weather. To avoid the situation, older seedlings with optimum growth need to be transplanted. It was reported that paddy yield was decreased significantly after transplanting of younger seedlings due to its higher mortality rate in the field while transplanting of older seedlings resulted in better performances [21]. In most of the above citations, transplanting rice at different ages of ~~HYVs~~high-yielding varieties ~~/~~or modern varieties have ~~shown~~ have been studied for the variation in their performances in respect of yield but local varieties ~~of Boro season~~ have not been tested in Boro season. The major objectives of the study ~~were~~ was to know the effect of seedling age at transplanting on the growth and yield performances of high yielding and local varieties of Boro season in Sylhet region, Bangladesh.

2. MATERIALS AND METHODS

The experiment was conducted during the period from November 2012 to May 2013 at Patnipara, Chicknagul union under Jointapur upazila of Sylhet district, 18 km far North-East from Sylhet Agricultural University, Sylhet. Geographically the location is situated at 23° to 25°1′ North and 90°57′ to 92°28′ East longitude and latitude, respectively with an elevation of 34 m above the mean sea level. The experimental field had fairly leveled topography: medium low land ~~and~~ with a good drainage system. The experimental plot was under the Agro-ecological zone 20 and the soil type was silty clay loam in texture and pH of the soil was about 5.5-6.5. Organic matter content of the soil was moderate. Levels of cation exchange capacity (CEC) and Zn ~~was~~ were medium while the status of P, K and B was low. Sylhet has a tropical climate ~~and~~ as the monsoon clouds blow in the area throughout the year~~,~~. ~~there~~ There ~~is~~ is a considerable rainfall in most of the months of the year while June and July receive the highest amount. This area is much cooler and hotter than the other parts of Bangladesh. Monthly maximum and minimum temperature, rainfall and relative humidity during the crop growing period have been presented in Table 1.

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Table 1. Monthly average rainfall, minimum and maximum temperatures and relative humidity during the study period from November 2012-June 2013

Month	Year	Rainfall (mm)	Air Temperature (°C)			Relative Humidity (%)
			Maximum	Minimum	Average	
November	2012	11.9	29.2	18.9	24.1	68
December	2012	Nil	25.0	14.5	19.8	75
January	2013	Nil	25.6	11.8	18.7	63
February	2013	2.3	31.2	15.9	23.6	49
March	2013	1.9	36.2	19.7	27.8	47
April	2013	13.9	33.0	21.9	27.5	59
May	2013	34.2	30.4	22.7	26.6	78
June	2013	26.9	33.9	25.8	29.9	75

Source: Department of Meteorology, Sylhet

The treatments included in the experiment were as follows.

Factor A. Variety: 4

i. BRRI dhan28 (V_1)
ii. BRRI dhan29 (V_2)
iii. Khoiaboro (V_3)
iv. Begunbichi (V_4)

Factor B. Seedling age at transplanting: 3

i. 15 days old seedlings (15DOS)
ii. 20 days old seedlings (20DOS)
iii. 25 days old seedlings (25DOS)

Among the varieties BRRI dahn28 and BRRI dahn29 were the High Yielding Varieties (HYV) and Khoiaboro and Begunbichi (aromatic) were the local or indigenous varieties of rice. The experiment was laid out according to a factorial ~~R~~randomized ~~Complete~~ complete ~~Block~~ block ~~Design~~ design ~~(Factorial)~~. The unit plot size was 3 m x 2 m. Seed was used at the rate of 10 kg ha^{-1} having germination percentage of 93%, 95%, 92% and 95% for BRRI dhan28, BRRI dhan29, Khoiaboro and Begunbichi, respectively. Pre-germinated seeds of all varieties were sown in nursery beds on 23rd November 2012 (for 25 days old seedlings), 28th November 2012 (for 20 days old seedlings) and 03rd December 2012 (for 15 days old seedlings). Frequent irrigation was done to maintain enough moisture content in the seed bed. Field was prepared ~~by power tiller on 1 December 2012 with a power tiller i.e. 15~~fifteen days before

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transplanting by power tiller. Organic manures and inorganic fertilizers were applied in the field. The source of organic manures was cow-dung and it applied at the rate of 10 t ha^{-1} as basal application 10 days before final land preparation. Fertilizers were applied as suggested by BRRI (2011) [3] at the rate of 138-20-60-20-4 kg ha^{-1} NPKS & Zn for the variety of BRRI dhan29, 121-20-60-20-4 kg ha^{-1} NPKS & Zn for BRRI dhan28, 52-15-15 kg ha^{-1} of NPK, respectively and 5 t ha^{-1} of Cow-dung as basal for both the local varieties of Khoiaboro and Begunbichi. N, P, K, S and Zn were applied through Urea, TSP, ~~MoP~~MoP, Gypsum and $ZnSO_4$, respectively. Urea was applied into three installments- $1/3^{rd}$ at final land preparation, $1/3^{rd}$ at 21 days after transplanting (DAT) (tillering stage) and $1/3^{rd}$ at 36 DAT (active tillering stage) in each plot. The nursery beds were made wet by application of water both in morning and evening on the previous day of uprooting the seedlings. Seedlings were uprooted carefully so that minimum damage was done to the root system and uprooted seedlings kept in shade before transplanting. The methods were followed for each case of uprooting and transplanting for different ages of seedling. The seedlings uprooted from the nursery bed were transplanted on the same day. Single seedling of each 15, 20 and 25 days old was transplanted in a square pattern maintaining 25 cm × 25 cm spacing on the well puddled plots on 16 December 2012. During transplanting of seedling the plot was saturated with sufficient 2-3 cm depth of water. To maintain the desired plant population in each plot, gap filling was done within 10 days of transplanting as some hills died off using seedling of the same source of the respective age. The first manual weeding was done at 21 DAT after which first top dress of urea was done. Second top dress of urea was done after second weeding at 36 DAT for each crop. At both weeding and top dressing sufficient moisture was ensured in each plot. Water management was done properly following flood irrigation method with the help of shallow tubewell from surface water. After transplanting 3-4 cm water depth was maintained throughout the life cycle of the crop but removed 10 days before maturity. For controlling insect-pest granular insecticide Carbofuran 5G (Furadan) was applied at the rate of 16 kg ha^{-1} by maintaining 4-5 cm water depth in the crop field at maximum tillering stage. Crop maturity was determined when 80% grain of all panicles in a plot turned into golden yellow in colour except Khoiaboro. Grain colour of Khoiaboro rice was blackish yellow. At this stage culm and leaves were also turn into yellow colour. At maturity ten random hills were sampled for collection of data on yield and yield attributes. BRRI dhan28 was harvested on 12, 19, 25 April 2013 respectively for the seedling age of 25 days old, 20 days old and 15 days old, respectively. BRRI dhan29 was harvested on 2, 9 and 15 May 2013 April, respectively of the seedling age of 25 days old, 20 days old and 15 days old. Khoiaboro was harvested on 12, 16 and 18 April 2013 of the seedling age of 25

days old, 20 days old and 15 days old, respectively and Begunbichi was harvested on 12, 20 and 24 April 2013 of the seedling age of 25 days old, 20 days old and 15 days old, respectively. First of all, border row from each side were harvested and these were excluded from final threshing. Remaining net plot area was harvested manually at ground level using sickle and kept separately for recording crop yield plot wise. Then grains were separated from each bundle by beating with bamboo sticks and grains were dried in the sun. Then moisture was recorded with moisture meter (GMK-303RS) and grain weight of individual plot was adjusted at 12% moisture content. After thorough sun drying straw weight was recorded separately. Finally, grain and straw weights in kg plot^{-1} of the individual plot were converted into t ha^{-1}. Data were collected on the growth, yield and yield attributes as follows.

i. Number of tiller plant^{-1} at every 10-day intervals
ii. Days to 50% flowering (when at least 50% tillers had panicle in each plot).
iii. Days to maturity
iv. Plant height at harvest
v. Total number of tillers hill^{-1}
vi. Number of effective tillers hill^{-1}
vii. Number of non-effective tillers hill^{-1}
viii. Length of panicle
ix. Total number of spikelets panicle^{-1}
x. Number of grains panicle^{-1}
xi. Number of unfilled grains panicle^{-1}
xii. 1000 grain weight
xiii. Grain weight plot^{-1}
xiv. Straw weight plot^{-1}
xv. Biological yield
xvi. Harvest index

Number of total tillers was counted from the selected five hills at every 10 day intervals. Tillers were counted by spreading the base of each standing hill so that small tiller may not be left out. Number of tillers counted in each date from five hills was averaged for individual plot and this data were statistically analyzed.

Harvest index (HI) was calculated on the basis of grain and straw yields using the following formula and expressed in percentage [13].

Where, Biological Yield= Grain yield + Straw yield

Statistical analysis

The collected data were tabulated and these were analyzed using computer software MSTATC (Ref?). Mean separations were done at 5% level of significance by Least Significant Difference (LSD) Test wherever F values were significant at either 0.01% or 0.05% level of probability.

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3. RESULTS AND DISCUSSION

Number of tillers hill^{-1} at 10-day intervals

Individual effect of variety and seedling age has not been discussed here as interaction effect of variety and seedling age was found significant for number of tillers hill^{-1} at 10-day intervals at most of the cases. Interaction effect of variety and seedling age was found non-significant for number of tillers hill^{-1} at 40 DAT but at 50 DAT (Figure 1). The highest number of tillers (14.00 hill^{-1}) was recorded from the combination of V_2×25DOS and the lowest (1.89 hill^{-1}) was obtained from the combination of V_3×15DOS at 50 DAT. The result indicated that at 60 DAT, the combination of V2×25DOS produced maximum number of tillers (25.66 hill^{-1}) which was statistically similar to that of V_2×20DOS (23.67 hill^{-1}) and minimum (6.88 hill^{-1}) was found in the combination of V_3×15DOS. Number of tillers hill^{-1} was significantly affected by the interaction of variety and seedling age at 70 DAT. The maximum number of tillers (33.67 hill^{-1}) was recorded from the combination of V_1×25DOS which was statistically similar to that of V_2×20DOS (29.78 hill^{-1}) and V_2×25DOS (32.22 hill^{-1}). The minimum number of tillers (14.56 hill^{-1}) was obtained from the combination of V_4×15DOS similar to that of V_2×15DOS (16.65 hill^{-1}) and V_3×15DOS (17.33 hill^{-1}).

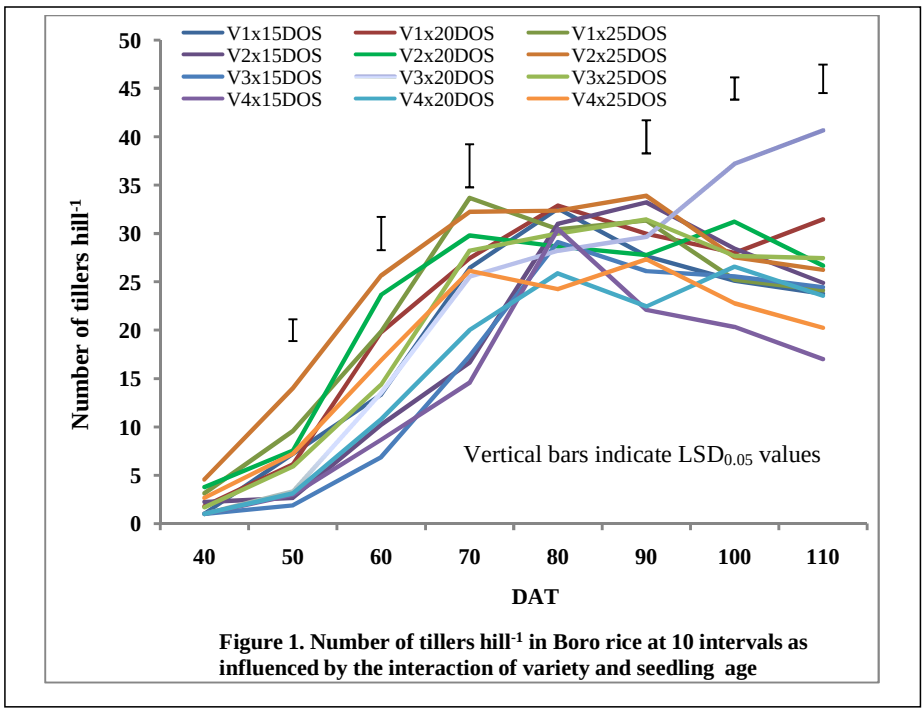

Figure 1. Number of tillers hill^{-1} in Boro rice at 10 intervals as influenced by the interaction of variety and seedling age

The interaction effect of variety and seedling age was non-significant for number of tillers hill^{-1} at 80 DAT while the same was significant at 90 DAT (Figure 1). The highest number of tillers (33.89 hill^{-1}) was recorded in the combination of V_2×25DOS which was statistically similar to that of V_2×15DOS (33.22 hill^{-1}), V_1×25DOS (31.33 hill^{-1}) and V_3×25DOS (31.44 hill^{-1}) combinations. On the other hand, the lowest number of tillers (22.11 hill^{-1}) was found in the combination of V_4×15DOS which was statistically at par with that of V_4×20DOS (22.44 hill^{-1}). The result revealed that older seedling produced more number of tillers hill^{-1}. Interaction of variety and seedling age produced significant effect on the number of tillers hill^{-1} at 100 DAT and the results showed that the highest number of tillers (37.22 hill^{-1}) was produced by the combination of V_3×20DOS while the lowest (20.33 hill^{-1}) was produced by the combination of V_4×15DOS. The highest number of tiller (40.67 hill^{-1}) was obtained due to the treatment combination of V_3×20DOS which was significantly different from the others while the lowest (17.00 hill^{-1}) was obtained in the combination of V_4×15DOS at 110 DAT.

Phenology, yield components and yield

Varietal performances

Maximum days to 50% flowering (115.0) was recorded from the variety Begunbichi and minimum days to flowering (97.3) was recorded from the variety Khoiaboro (Table 2). Both the varieties BRRI dhan29 and Begunbichi took maximum days for their maturity (141.8) while Khoiaboro took the minimum days for maturity (122.0) (Table 2). Plant height was significantly varied among the varieties irrespective of seedling age. Result revealed that the local variety Begunbichi produced the tallest plant (154.49 cm) which was significantly different from the others. Moderate plant height was found in Khoiaboro whilst the shortest plant (96.82 cm) was found in BRRI dhan29 which was statistically similar to that of BRRI dhan28 (100.33 cm). Both the local varieties produced the taller plant and HYV's produced the shorter might be due to genetic variations of the varieties (Table 2). Total number of tillers hill^{-1} included effective and non-effective tillers was significantly differed among the varieties. It is evident that maximum number of tillers (27.20 hill^{-1}) was obtained from the local variety Khoiaboro which was significantly different from the others. Minimum total number of tillers (20.70 hill^{-1}) was found in the local aromatic variety Begunbichi. BRRI dhan28 and BRRI dhan29 produced statistically similar number of total tillers (22.30 and 22.70 hill^{-1}, respectively) to the local variety Begunbichi (Table 2). The highest number of effective tillers (22.51 hill^{-1}) was found in the variety Khoiaboro which was significantly different from the others (Table 2). The Begunbichi produced the lowest number of effective tillers (16.41 hill^{-1}) while both the varieties BRRI dhan28 and BRRI dhan29 produced moderate number of effective tillers hill^{-1}. Venugopal and Singh (1985) obtained the highest number of effective tillers in short duration rice variety [40]. There was significant variation among the varieties in respect of number of non-effective tillers hill^{-1}. Both the varieties Khoiaboro and Begunbichi produced statistically similar number of non-effective tillers (4.7 and 4.3 hill^{-1}, respectively) having the highest in the variety Khoiaboro. The lowest number of non-effective tillers (3.0 hill^{-1}) was found in the variety BRRI dhan29 which was statistically similar to the variety BRRI dhan28. The variety BRRI dhan28 also produced similar number of non-effective tillers hill^{-1} to the varieties Khoiaboro and Begunbichi. The varieties differed significantly in terms of length of panicle. BRRI dhan29 and Begunbichi had statistically similar panicle length having the highest value (25.0 cm) in the variety Begunbichi. The variety Khoiaboro had the lowest panicle length (20.0 cm) which was similar to that of BRRI dhan28 (22.2 cm) (Table 3). There was also significant variation in terms of total number of filled and unfilled spikelets panicle^{-1}. The variety Begunbichi produced maximum total number of spikelets (200.89

panicle^{-1}) while the variety Khoiaboro produced minimum (87.57 panicle^{-1}). BRRI dhan29 produced the second highest total number of spikelets (177.92 panicle^{-1}) which was significantly different from that of BRRI dhan28 (141.29) (Table 3). Variation was found significant among all varieties in respect of number of grains panicle^{-1}. Significantly highest number of grains (163.92 panicle^{-1}) was found in the variety Begunbichi followed by BRRI dhan29 while the lowest number (69.18 panicle^{-1}) was found in the variety Khoiaboro (Table 3).

Table 2. Phenology and yield components of rice varieties during Boro season 2012-2013

Varieties	Days to 50% flowering	Days to maturity	Plant height (cm) at harvest	Total number of tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
V_1	101.7^{b}	126.8^{b}	100.33^{c}	22.14^{b}	18.11^{b}	4.0^{ab}
V_2	114.3^{a}	141.8^{a}	96.82^{c}	21.69^{b}	18.72^{b}	3.0^{b}
V_3	97.3^{c}	122.0^{c}	146.02^{b}	27.20^{a}	22.51^{a}	4.7^{a}
V_4	115.0^{a}	141.8^{a}	154.49^{a}	20.72^{b}	16.41^{c}	4.3^{a}
CV(%)	2.11	1.55	3.73	9.70	8.85	27.54
$LSD_{0.05}$	2.206	2.015	4.542	2.121	1.638	1.077

Note: V_1= BRRI dhan28, V2=BRRI dhan29, V3= Khoiaboro, V_4= Begunbichi; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability.

Maximum number of unfilled spikelets (56.8 panicle-1) was found in BRRI dhan29 and the local variety Khoiaboro produced the minimum (18.4 panicle^{-1}) (Table 3). The second highest number of unfilled spikelets of 37.3 panicle^{-1}was found in the variety Begunbichi and it was 32.7 panicle^{-1} in BRRI dhan28.

Table 3. Yield components of rice varieties during Boro season 2012-2013

Variety	Length of panicle (cm)	Total number of spikelets panicle^{-1}	Number of grains panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grain weight (g)
V_1	22.2^{b}	141.29^{c}	108.63^{c}	32.69^{c}	22.01^{a}
V_2	24.7^{a}	177.92^{b}	121.09^{b}	56.82^{a}	22.38^{a}
V_3	22.0^{b}	87.57^{d}	69.18^{d}	18.40^{d}	20.81^{b}
V_4	25.0^{a}	200.89^{a}	163.92^{a}	37.30^{b}	12.10^{c}
CV(%)	5.21	3.88	6.53	9.26	4.05
$LSD_{0.05}$	1.197	5.769	7.382	3.287	0.765

Note: V_1= BRRI dhan28, V_2=BRRI dhan29, V_3= Khoiaboro, V_4= Begunbichi; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability.

Statistically similar 1000 grain weight was found in both varieties BRRI dhan28 and BRRI dhan29 and having maximum (22.38 g) in BRRI dhan29 (Table 3). The variety Begunbichi gave the minimum 1000 grain weight (12.10 g) which was significantly different from others. Significant variation was also observed among varieties in terms of grain yield. The result showed that the highest grain yield (6.25 t ha^{-1}) was produced in BRRI dhan29 followed by BRRI dhan28 (5.37 t ha^{-1}) whilst the lowest (2.26 t ha^{-1}) was obtained in the local variety Begunbichi (Table 4). The highest grain yield in BRRI dhan29 was possibly attributed by the higher number of effective tillers $hill^{-1}$ and grains $panicle^{-1}$. In spite of lower number of effective tillers $hill^{-1}$ in BRRI dahn28 than Khoiaboro grain yield was compensated in BRRI dhan28 probably due to its higher number of grains as well as larger grain size. On the contrary, the local variety Begunbichi had the highest number of grains $panicle^{-1}$ but due to its lower number of tillers $hill^{-1}$ and smallest grain size the variety produced the lowest grain yield (Table 4). The variety Khoiaboro produced maximum straw yield (6.86 t ha^{-1}) among the variety irrespective of seedling age which was statistically similar to that of BRRI dhan29 (6.82 t ha^{-1}) (Table 4). Moderate straw yield (5.71 t ha^{-1}) was found in BRRI dhan28 and the minimum straw yield (4.88 t ha^{-1}) was found in the local variety Begunbichi. Local variety Khoiaboro produced maximum straw yield might be due to its taller plant stature but in spite of taller plant in Begunbichi lowest straw yield was produced might be due to its thin plant stature.

Table 4. Yield and harvest index of rice varieties during Boro season 2012-2013

Varieties	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	5.37^{b}	5.71^{b}	11.08^{b}	48.60^{a}
V_2	6.25^{a}	6.82^{a}	13.07^{a}	47.95^{a}
V_3	2.90^{c}	6.86^{a}	9.77^{c}	30.09^{b}
V_4	2.26^{d}	4.88^{c}	7.14^{d}	31.78^{b}
CV(%)	10.54	8.42	7.06	7.67
$LSD_{0.05}$	0.432	0.499	0.708	2.968

Note: V_1= BRRI dhan28, V_2=BRRI dhan29, V_3= Khoiaboro, V_4= Begunbichi; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability.

Variation on biological yield was also found significant among the varieties. BRRI dhan29 gave the maximum biological yield (13.07 t ha^{-1}) while the minimum biological yield (7.14 t ha^{-1}) was found in the variety Begunbichi (Table 4). BRRI dhan28 had biological yield of 11.08 t ha^{-1} followed by that of

Khoiaboro (9.77 t ha^{-1}) which was significantly different from each others. The result revealed that variety BRRI dhan28 gave the highest HI (48.67%) and it was ~~identical~~ statistically similar to that of BRRI dhan29 (47.95%). There were statistically identical harvest indices of 30.09% and 31.78% of the local varieties Khoiaboro and Begunbichi (Table 4). This results ~~indicated~~ indicates that assimilate partitioning is more in the grains of ~~HYV's~~ high yielding varieties s than ~~the~~ that of in the local varieties which in turn resulted larger size of seed as well as higher grain yield in HYV's.

Effect of seedling age

Planting 20 days old seedlings took maximum duration for 50% flowering (110.9 days) and 15 days old seedlings took minimum duration for flowering (103.5 days) (Table 5). The results confirmed ~~with~~ the findings of Raju *et al*. (1989) who stated that days to flowering delayed in case of planting older seedlings [29]. But Padalia (1981) observed that days from sowing to flowering decreased with the increase of seedling age at planting [27]. Planting 25 days old seedlings took maximum duration for maturity (136.4 days) while planting 15 days old seedlings took minimum (130.3 days) (Table 5). Plant height did not vary significantly by the seedling age. However, plant height ranged from 123.06 cm in planting 15 days old seedlings to 125.97 cm in planting 20 days old seedlings (Table 5). Planting 25 days old seedlings produced shorter plant of 124.23 cm than that of planting 20 days old seedlings. Similar result has been reported by Murthy *et al*. (1993) [25]. Gani *et al*. (2002) reported that younger seedlings produced taller plant than older [12]. Total number of tillers $hill^{-1}$ as well as number of effective tillers $hill^{-1}$ did not vary significantly due to variation of seedling age. The results revealed that number of effective tillers ranged from 18.14 $hill^{-1}$ in planting 20 days old seedlings to 19.55 $hill^{-1}$ in planting 25 days old seedlings (Table 5). The results are in partial conformity with that of Mannan and Siddique (1991) [23]. On the contrary, Das *et al*. (1988) obtained higher tillers $hill^{-1}$ in younger seedling [8].

Table 5. Phenology and yield attributes of rice as influenced by seedling age during Boro season 2012-2013

Age of seedlings	Days to 50% flowering	Days to maturity	Plant height (cm) at harvest	Total number of tillers $hill^{-1}$	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$
15DOS	103.5[c]	130.3[c]	123.06	23.09	19.13	3.9
20DOS	106.8[b]	132.6[b]	125.97	22.22	18.14	4.0

25DOS	110.9[a]	136.4[a]	124.23	23.50	19.55	3.9
CV(%)	2.11	1.55	3.73	9.70	8.85	27.54
$LSD_{0.05}$	1.910	1.745	NS	NS	NS	NS

Note: 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability; NS = Not significant.

Variation of ~~N~~number of non-effective tiller $hill^{-1}$ ~~variation~~ was not significant and it was found that number of non-effective tiller was about 4.0 $hill^{-1}$ for different ages of seedling (Table 5).

Table 6. Yield attributes of rice as influenced by seedling age during Boro season 2012-2013

Age of seedlings	Length of panicle (cm)	Total number of spikelets $panicle^{-1}$	Number of grains $panicle^{-1}$	Number of unfilled spikelets $panicle^{-1}$	1000 grain weight (g)
15DOS	23.6	143.74[c]	111.8[b]	32.0[c]	19.52
20DOS	23.3	151.57[b]	114.8[ab]	36.8[b]	19.07
25DOS	23.7	160.44[a]	120.6[a]	40.1[a]	19.39
CV(%)	5.21	3.88	6.53	9.26	4.05
LSD $_{0.05}$	NS	4.996	6.393	2.847	NS

Note: 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability; NS = Not significant.

Length of panicle did not vary significantly due to variation in the age of seedling in this experiment. Rao and Raju (1987) also recorded similar findings and they stated that seedling age produced no significant effect on panicle length of rice [30]. But Singh *et al.* (2004) concluded that planting 21 days old seedlings produced higher panicle length than that of planting 31, 41 and 51 days old seedlings [34]. A significant variation was found in terms of total number of spikelets $panicle^{-1}$. The highest number of spikelets (160.4 $panicle^{-1}$) was obtained from planting 25 days old seedlings. Planting 15 days old seedlings produced the lowest number of spikelets (143.7 $panicle^{-1}$) (Table 6). The results exhibited that there was significant variation in terms of number of grains $panicle^{-1}$. The highest number of grains (120.4 $panicle^{-1}$) was found in the planting 25 days old seedlings and the lowest number of grains (111.7 $panicle^{-1}$) was found in planting 15 days old seedlings (Table 6). Number of grains of 114.7 $panicle^{-1}$ was produced in planting 20 days old seedlings. The result did not agree with many other scientists [15, 29, 33]. Planting 25 days old seedlings had significantly highest number of unfilled spikelets (40.1 $panilce^{-1}$) while planting 15 days old seedlings produced the lowest (32.0 $panicle^{-1}$) (Table 6). Reddy and Narayana (1981) observed that spikelet sterility decreased with the increased seedling age [32]. But Gill and Shahi (1987) opined that spikelet sterility increased in the older seedlings [14]. Seedling age

also failed to produce significant variation in respect of 1000 grain weight. It was found that planting 15, 20 and 25 days old seedlings gave 19.52, 19.07 and 19.39 g 1000 grain weight, respectively (Table 6). The result did not agree with the findings of Sunder Singh *et al*. (1983) who opined that 1000 grain weight increased significantly with the increase of seedling age [37]. On the contrary, Kamdi *et al.* (1991) reported that 1000 grain weight reduced with transplanting older seedlings [20]. Seedling age showed a significant influence on grain yield. The result presented in Table 7 showed that grain yield increased with the increase of seedling age. Planting 25 days old seedlings gave the highest grain yield (4.49 t ha^{-1}) and it was significantly different from other treatments. Planting 20 days old seedlings produced grain yield of 4.23 t ha^{-1} which was statistically similar to that of both planting 25 and 15 days old seedlings. The lowest grain yield of 3.86 t ha^{-1} was obtained from planting 15 days old seedlings (Table 7). Higher grain yield in planting 25 days old seedlings was ascribed to mainly by the higher number of grains $panicle^{-1}$. Initial higher leaf area and photosynthesis, and less respiration loss for tiller production than 15 and 20 days old seedlings helped to produce more early dry matter accumulation which in turn might augment formation of more number of grain in planting 25 days old seedlings. The results are in close conformity with that of Teetharappan and Palaniappan (1984) who stated that planting 25 days old seedlings gave the highest grain yield of rice [38]. Prasad *et al.* (1992) reported that grain yield increased with the seedling age at transplanting up to 35 days old [28]. Rashid *et al*. (1990) opined that planting 40 days old seedlings gave higher grain yield than that of planting 20 or 60 days old seedlings [31].

Table 7. Yield and harvest index of rice as influenced by seedling age during Boro season 2012-2013

Age of seedlings	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
15DOS	3.86^{b}	5.25^{c}	9.11^{c}	40.79
20DOS	4.23^{ab}	6.19^{b}	10.40^{b}	39.33
25DOS	4.49^{a}	6.78^{a}	11.27^{a}	38.70
CV(%)	10.54	8.42	7.06	7.67
$LSD_{0.05}$	0.374	0.435	0.613	NS

Note: 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability; NS = Not significant.

The highest straw yield of 6.78 t ha^{-1} was obtained from planting 25 days old seedlings while the lowest of 5.25 t ha^{-1} was obtained from planting 15 days old seedlings. Planting 20 days old seedlings produced 6.19 t ha^{-1} straw yield which was significantly different from all other seedling ages (Table 7). The result indicated that planting 20 days old seedlings had a little bit higher plant height as well as total number of tillers $hill^{-1}$ which might be attributed to produce more straw yield. The lowest straw yield was obtained from planting 15 days old seedlings because of little bit lower plant height and tillering capacity than others. Planting 40 days old seedlings produced higher straw yield than that of planting 20 or 60 days old seedlings [31]. Furuk *et al*. (2009) also stated that planting 2 weeks old seedlings gave the lowest straw yield than planting 4 weeks old seedlings of rice [11]. Biological yield was significantly influenced by seedling age. The highest biological yield (11.27 t ha^{-1}) was obtained from planting 25 days old seedlings whilst the lowest biological yield (9.11 t ha^{-1}) was recorded from planting 15 days old seedlings. The result clearly indicated that biological yield was increased with increase of seedling age from planting 15 to 25 days old (Table 7). Harvest index (HI) was not influence significantly due to seedling age (Table 7). The highest HI (40.79%) was obtained from planting 15 days old seedlings. Planting of both 20 and 25 days old seedlings gave harvest indices of 39.33% and 38.70%, respectively.

Interaction effect of variety and seedling age

The result exhibited that BRRI dhan29 took maximum days for 50% flowering (121.3 days) with planting 25 days old seedlings closely followed by Begunbichi (119.0 days) (Table 8). Khoiaboro took the minimum duration for 50% flowering (91.67 days) at planting 15 days old seedlings. It was found that the variety BRRI dhan29 took the maximum days for maturity (146.0) closely followed by the variety Begunbichi (145.3) at planting 25 days old seedlings. The variety Khoiaboro took minimum days (116.7) for its maturity (Table 8). Variations of plant height at harvest, total number of tillers $hill^{-1}$ and number of non-effective tillers $hill^{-1}$ due to the interaction of variety and seedling age were not significant. Interaction of varieties and ages of seedling exerted significant influence on number of effective tillers $hill^{-1}$. The results revealed that the combination of V_3×25DOS gave the highest number of effective tillers (25.47 $hill^{-1}$) while the combination V_4×20DOS gave the lowest (15.67 $hill^{-1}$) (Table 8). The combinations of V_1×25DOS, V_4×15DOS and V_4×25DOS also produced statistically similar number of effective tillers $hill^{-1}$ to that of V_4×20DOS. Actually there was no consistent trend in respect of the number of effective tillers $hill^{-1}$ with different seedling ages for different varieties.

Table 8. Phenology and yield attributes of rice as influenced by the interaction of variety and seedling age during Boro season 2012-2013

Interaction (Variety × Seedling age)	Days to 50% flowering	Days to maturity	Plant height (cm) at harvest	Total number of tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
V_1×15DOS	101.0^{d}	126.3^{de}	101.43	23.63	19.37^{bcd}	4.27
V_1×20DOS	101.3^{d}	125.7^{de}	100.60	22.76	18.77^{bcde}	4.00
V_1×25DOS	102.7^{d}	128.3^{d}	98.97	20.03	16.20^{ef}	3.83
V_2×15DOS	111.7^{c}	140.7^{bc}	93.63	22.00	19.27^{bcd}	2.73
V_2×20DOS	110.0^{c}	138.7^{c}	98.10	20.03	17.07^{cdef}	2.97
V_2×25DOS	121.3^{a}	146.0^{a}	98.73	23.03	19.83^{bc}	3.20
V_3×15DOS	91.67^{e}	116.7^{f}	142.53	25.50	21.00^{b}	4.50
V_3×20DOS	99.67^{d}	123.3^{e}	151.30	26.23	21.07^{b}	5.17
V_3×25DOS	100.7^{d}	126.0^{de}	144.23	29.86	25.47^{a}	4.40
V_4×15DOS	109.7^{c}	137.3^{c}	154.63	21.23	16.87^{def}	4. 37
V_4×20DOS	116.3^{b}	142.7^{ab}	153.87	19.86	15.67^{f}	4. 20
V_4×25DOS	119.0^{ab}	145.3^{a}	154.97	21.06	16.70^{def}	4. 37
CV(%)	2.11	1.55	3. 73	9.70	8.85	27. 54
$LSD_{0.05}$	3.821	3.491	NS	NS	2.837	NS

Note: V_1= BRRI dhan28, V_2=BRRI dhan29, V_3= Khoiaboro, V_4= Begunbichi, 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability; NS = Not significant.

Interaction of variety and seedling age was found non-significant in respect of length of panicle and total number of spikelets panicle^{-1}. Number of grain panicle^{-1} also did not vary significantly due to interaction of variety and seedling age (Table 9). Number of unfilled spikelets panicle^{-1} varied significantly due to the interaction of variety and seedling age. The results exhibited that the variety V_2 (BRRI dhan29) had significantly highest number of unfilled spikelets panicle^{-1} (62.5) along with planting 25 days old seedlings (Table 9). It is evident that variety V_3 (Khoiaboro) produced the lowest number of unfilled spikelets panicle^{-1} (11.0) with planting 15 days old seedlings which was statistically identical to that of planting 20 days old seedlings (14.6 panicle^{-1}) of the same variety. A moderate number of unfilled spikelets panicle^{-1} was observed in both the varieties V_1 (BRRI dhan28) and V_4 (Begunbichi) with all seedling ages.

Table 9. Yield attributes of rice as influenced by the interaction of variety and seedling age during Boro season 2012-2013

Interaction (Variety × Seedling age)	Length of panicle (cm)	Total number of spikelets panicle^{-1}	Number of grains panicle^{-1}	Number of unfilled spikelets panicle^{-1}	1000 grain weight (g)
V_1×15DOS	22.10	136.30^{f}	105.5^{e}	30.9^{d}	22.27
V_1×20DOS	21.83	148.63^{e}	115.7^{de}	32.87^{d}	22.10
V_1×25DOS	22.63	138.93^{ef}	104.7^{e}	34.2^{d}	21.67
V_2×15DOS	25.73	166.70^{d}	113.5^{de}	53.2^{b}	21.97
V_2×20DOS	23.93	174.93^{d}	120.2^{cd}	54.7^{b}	23.03
V_2×25DOS	24.57	192.13^{bc}	129.6^{c}	62.5^{a}	22.13
V_3×15DOS	21.83	86.70^{h}	75.7^{f}	11.0^{e}	21.17
V_3×20DOS	22.33	66.03^{i}	51.5^{g}	14.6^{e}	20.17
V_3×25DOS	21.87	109.97^{g}	80.4^{f}	29.6^{d}	21.10
V_4×15DOS	24.57	185.27^{c}	152.4^{b}	32.9^{d}	12.67
V_4×20DOS	24.97	216.67^{a}	171.7^{a}	45.0^{c}	10.97
V_4×25DOS	25.53	200.73^{b}	167.7^{a}	34.0^{d}	12.67
CV(%)	5.21	3.88	6.53	9.26	4.05
LSD $_{0.05}$	NS	9.993	12.79	5.693	NS

Note: V_1= BRRI dhan28, V_2=BRRI dhan29, V_3= Khoiaboro, V_4= Begunbichi, 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings. Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability. NS = Not significant.

The results revealed that interaction of variety and seedling age failed to produce significant effect on 1000 grain weight. The values of 1000 grain weight presented in Table 9 indicated that the varieties V_1, V_2 and V_3 had comparatively larger sized grain (ranged from 20.17 g to 23.03 g) while V_4 had small sized grain (ranged from 10.97 g to 12.67 g). Grain yield was not significantly varied due to interaction of variety and seedling age (Table 10). The results indicated that all varieties included in the experiment required a particular seedling age for producing maximum grain yield.

Table 10. Yield and harvest index of rice as influenced by the interaction of variety and seedling age during Boro season 2012-2013

Interaction (Variety × Seedling age)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1×15DOS	5.24	5.50^{cd}	10.74^{b}	49.19
V_1×20DOS	5.42	5.59^{cd}	11.01^{b}	49.28
V_1×25DOS	5.44	6.04^{bc}	11.48^{b}	47.33

V_2×15DOS	5.58	5.63^{cd}	11.20^{b}	49.83
V_2×20DOS	6.23	7.96^{a}	14.19^{a}	43.78
V_2×25DOS	6.94	6.88^{b}	13.81^{a}	50.23
V_3×15DOS	2.66	5.84^{cd}	8.50^{cd}	31.32
V_3×20DOS	2.98	6.13^{bc}	9.10^{c}	32.70
V_3×25DOS	3.07	8.62^{a}	11.69^{b}	26.24
V_4×15DOS	1.97	4.04^{e}	6.01^{e}	32.81
V_4×20DOS	2.30	5.00^{d}	7.30^{d}	31.54
V_4×25DOS	2.51	5.59^{cd}	8.10^{cd}	31.00
CV(%)	10.54	8.42	7.67	7.67
LSD $_{0.05}$	NS	0.865	1.227	NS

Note: V_1= BRRI dhan28, V_2=BRRI dhan29, V_3= Khoiaboro, V_4= Begunbichi, 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings; Figures within the same column having same or no letter(s) do not differ significantly at 5% level of probability. NS = Not significant.

Effect of interaction between variety and seedling age on straw yield was found significant. The highest straw yield (8.62 t ha^{-1}) was obtained from the combination of V_3×25DOS. The lowest straw yield (4.04 t ha^{-1}) was recorded from the combination of V_4×15DOS (Table 10). The combinations of V_1×15DOS, V_1×20DOS, V_1×25DOS, V_2×15DOS, V_3×15DOS and V_3×20DOS produced statistically similar straw yield. Significant variation was found in respect of biological yield due to interaction effect of variety and seedling age. The highest (14.19 t ha^{-1}) biological yield was obtained from the combination of V_2×20DOS which was statistically identical to that of V_2×25DOS (13.81 t ha^{-1}). The lowest biological yield (6.01 t ha^{-1}) was recorded from the combination of V_4× 15DOS (Table 10). The results indicated that the combinations of V_1×20DOS, V_1×25DOS and V_3×25DOS produced statistically similar biological yields of 11.01, 11.48 and 11.69 t ha^{-1}, respectively. The combinations of V_1×15DOS and V_2×15DOS also produced similar biological yields of 10.74 and 11.20 t ha^{-1}, respectively. Biological yields of 7.30 and 8.10 t ha^{-1} of the combinations of V_4×20DOS and V_4×25DOS were statistically similar. Interaction effect of variety and seedling age also produced significant influence on harvest index (HI). The highest HI (50.23%) was obtained from the combination of V_2×25DOS which was similar to the combinations of V_1×15DOS, V_1×20DOS and V_2×15DOS (Table 10). The lowest HI (26.24%) was obtained from the combination of V_3×25DOS which was significantly different from other combinations. The combinations of V_3×15DOS, V_3×20DOS, V_4×15DOS, V_4×20DOS and V_4×25DOS produced statistically similar HI's of 31.32%, 32.71%, 32.81%, 31.54% and 31.00%, respectively.

Economic performance

Total cost of cultivation was calculated maximum (US$ 965.73 ha^{-1}) in the variety BRRI dhan29 followed by the variety BRRI dhan28 (US$ 957.29 ha^{-1}). The maximum production cost incurred in the HYV's due to the requirement of more inputs for their production (Table 11). Maximum gross return (US$ 1665.00 ha^{-1}), net return (US$ 699.28 ha^{-1}) and BCR (1.72) were also obtained from the same variety BRRI dhan29 with planting 25 days old seedlings. The higher profitability obtained in BRRI dhan29 was due to its higher yield. It was found that cultivation of local variety 'Begunbichi' was more profitable than BRRI dhan28 with planting 25 days old seedlings and than Khoiaboro at all seedling ages. This was due to more market price of the scented grain of Begunbichi (US$ 0.43 kg^{-1}) compared to BRRI dhan28 (US$ 0.23 kg^{-1}). Cultivation of Khoiaboro was found less profitable due to its lower productivity as well as low market price because of its coarse size grains.

Table 11. Cost and return analysis of production of different rice varieties during Boro season 2012-2013

Interaction		Yield (t ha^{-1})		Total cost of cultivation (US$ ha^{-1})	Gross return (US$ ha^{-1})			Net return (US$ ha^{-1})	BCR
Variety	Seedling age	Grain	Straw		Grain	Straw	Total		
V_1	15DOS	5.24	5.50	957.29	1205.20	55.00	1260.20	302.91	1.32
	20DOS	5.42	5.59	957.29	1246.60	55.90	1302.50	345.21	1.36
	25DOS	5.44	6.04	957.29	1251.20	60.40	1311.60	354.31	1.37
V_2	15DOS	5.58	5.63	965.73	1283.40	56.30	1339.70	373.98	1.39
	20DOS	6.23	7.96	965.73	1432.90	79.60	1512.50	546.78	1.57
	25DOS	6.94	6.88	965.73	1596.20	68.80	1665.00	699.28	1.72
V_3	15DOS	2.66	5.87	611.66	558.60	58.70	617.30	5.64	1.01
	20DOS	2.98	6.13	611.66	625.80	61.30	687.10	75.44	1.12
	25DOS	3.07	8.62	611.66	644.70	86.20	730.90	119.24	1.19
V_4	15DOS	1.97	4.04	723.94	847.10	40.40	887.50	163.56	1.23
	20DOS	2.30	5.00	723.94	989.00	50.00	1039.00	315.06	1.44
	25DOS	2.51	5.53	723.94	1079.30	55.30	1134.60	410.66	1.57

Note: V_1= BRRI dhan28, V_2=BRRI dhan29, V_3= Khoiaboro, V_4= Begunbichi, 15DOS= 15 days old seedlings, 20DOS= 20 days old seedlings, 25DOS= 25 days old seedlings.

Selling price: Rice grain – US$ 0.23 kg^{-1} for both BRRI dhan28 and BRRI dhan29; US$ 0.21 kg^{-1} for Khoiaboro; US$ 0.43 kg^{-1} for Begunbichi; Straw- US$ 0.01 kg^{-1}; 1 US$= BDT 80; BCR = Benefit-Cost Ratio.

CONCLUSIONS

On the basis of the results obtained from the experiment lead to conclude that 25 days old seedlings was found to produce the highest grain yield and therefore, all High Yielding and local varieties are suggested to be grown with 25 days old seedlings. BRRI dhan29 gave the maximum economic benefit followed by Begunbichi a local aromatic Boro rice variety. Considering the profitability the local variety Begunbichi may also be suggested for cultivation in other parts of the country as there is only a high yielding fine rice variety BRRI dhan50.

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