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Optimizing seedling age of promising rice genotypes in rainfed environment

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ABSTRACT

To determine optimum seedling age and characterize the effect of seedling age on the performance of the rice genotypes, the experiment was conducted during wet season of 2010 and 2011 at Bangladesh Rice Research Institute, Regional Station, Rajshahi. Strip plot design was followed with 3 replications, placing treatments (seedling age such as 14, 21, 28 and 35-d old) in vertical plots and genotypes (BRRI dhan56, BRRI dhan57, IR83377-B-B-93-3, IRRI123, IR83381-B-B-6-1 and Binadhan-7) in horizontal plots. Seedling age had strong significant effect on yield, yield components and agronomic parameters. Transplanting of 14-d old seedlings gave the highest grain yield that was at par with 21-d old seedling, however, significantly higher than 28 and 35-d old seedlings. Mean grain yield were increased by 21.9, 20.5 and 12.2% in transplanting of 14, 21 and 28-d old seedlings over 35-d old seedlings. Reversely, yield declined by 1.7, 11.2 and 21.9% in 21, 28 and 35-d old seedlings over 14-d old seedlings, across the cropping years and genotypes. Across the seedling ages, the genotype IR83377-B-B093-3 produced the highest mean grain yield (4.88 t ha^{-1}) which was at par with IRRI 123 (4.82 t ha^{-1}) and the lowest was in BRRI dhan57 (3.73 t ha^{-1}). Interaction between genotypes and seedling ages showed that BRRI dhan56, BRRI dhan57 and IR83381-B-B-6-1 produced higher yield from 14 to 21-d old seedlings while Binadhan-7 gave at par yield from 14 to 28-d old seedling. In contrast, grain yield of IR83377-B-B-93-3 and IRRI 123 was statistically similar throughout the seedling age from 14 to 35-d old. Days to flowering and maturity increased 12 to 14 days from 14 to 35-d old seedlings. Spikelet sterility also increased by 18 to 23.1% from 14 to 35-d old seedlings. In contrast, Plant height, tillers and panicles m^{-2}, grains $panicle^{-1}$, 1000-grain weight, straw yield and total above ground biomass were declined with increased seedling age.

***Keywords*: Biomass, grain yield, panicle, rainfed environment, rice genotype, seedling age**

The demand of rice is increasing with the increasing population in Bangladesh. It is expected that the country will need to double its production in the next 40 years to cope with growing population. In addition, about 89 ha of agricultural land of Bangladesh is being lost every day because of shifting the cultivable land to non-agricultural uses such as housing, roads, institutions, industrial establishment etc. (Uddin, 2011). Therefore, it is a great challenge to feed the increasing population of Bangladesh, there is no other alternative than to increase rice yield through improving crop management practices. Rainfed lowland rice is the second most important rice ecosystem after the irrigated ecosystem, and it represents about 25% of total rice production area (Swamy and Kumar, 2012). Rainfed lowland rice is grown in non-irrigated bunded fields that are flooded with rain water for at least part of the cropping season at water depths that do not exceed 50 cm (Fujisaka, 1990). Seedling age is habitually increased in delayed transplanting in the wet season due to delayed rainfall in drought prone rainfed environments. Farmers in drought-prone rainfed environments often face drought during crop establishment, thereby forced to transplant relatively older seedlings (50 to 60-d old seedling). As a consequence, yield losses are sometimes thought to be the main reason for low average yields.

Seeding age at transplanting is one the most important factor that substantially influences yield and other agronomic parameters. Seedling age at transplanting varied depending on variety, season, land topography, cropping system and also availability of water, inputs, labor, etc in farmers' field. Farmers in the rainfed area of northwest Bangladesh transplant seedlings with a varied ages ranging from 20 to 45 days after seeding in wet season. The seedling age range is very high as farmers of rainfed environment mostly depend on rainfall to transplant seedlings. Similarly, farmers in the tropical lowland rice system transplant seedlings of diverse ages varying from 25 to 50 days (De Datta, 1981; Wagh *et al.,* 1988; Singh and Singh, 1999). However, many of the scientists reported better yield using seedling age below 25 days (Wagh *et al.,* 1988; Singh and Singh, 1998; Rao and Raju, 1987). Among the various factors that influence rice productivity, seedling age is rated high because it has tremendous effect on plant height, number of tiller and panicle production, panicle length, grain formation, yield and yield attributes (Ali *et al.,* 1995). Using optimum seedling age for transplanting is primarily important for seedling establishment, uniform crop stand and overall performance stated that "half of the success of rice cultivation depends upon seedling age" (Khakwani *et al.,* 2005). Management practices like optimum

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seedling age that ought to be affordable and support environmental sustainability must be developed. Therefore, research on optimizing seedling age is essential towards better understanding of the constraints and opportunities in rainfed rice cultivation.

MATERIALS AND METHODS

The experiment was conducted during wet season (June to November) of 2010 and 2011 at the Experimental Farm of Bangladesh Rice Research Institute (BRRI), Regional Station, Rajshahi (24°22" N latitude, 88°40" E longitude, 21 above msl) to determine the best seedling age at transplanting in varying genotypes under rainfed environment; and characterize the effect of seedling age on the performance of the different genotypes under High Gangetic River Floodplain Agro-ecological Zone (AEZ) 11. Experimental soils are silty loam to silty clay loam, calcareous and slightly alkaline in reaction (BARC, 2012). Six genotypes, namely, IR74371-70-1-1 (Released as BRRI dhan56 in 2011), BR7873-*5(NIL)-51-HR6 (Released as BRRI dhan57 in 2011), IR83377-B-B-93-3, IRRI 123, IR83381-B-B-6-1 and Binadhan-7 were used in the experiment with four seedling ages (14, 21, 28 and 35-d old). The experiment was laid out in a strip-plot design with 3 replications, placing seedling age treatments in vertical plots and genotypes in horizontal plots. Unit plot size was 12 m^2. Seeds of the genotypes were sown at 4 dates with 7 days interval according to the treatments, but seedlings of all treatments were transplanted on the same day. Seedlings of different ages based on treatment schedule were transplanted on 5 August 2010 and 1 August 2011, at 3 seedlings $hill^{-1}$ spaced at 20 cm x 15 cm. Uniform crop management practices were followed for each treatment. Date of seeding, transplanting, flowering (50%) and maturity (80%) were recorded in time. Plant height was measured from 5 randomly-selected plants from each plot, from the ground level to the tip of the panicle at maturity stage. At maturity, tillers and panicles per unit area were counted from 2 x 2 hill sampling units from three places (12 hills $plot^{-1}$) diagonally in each plot (Gomez, 1983). The sample hills were selected excluding border and harvest area. The sample hills were not hills that were replanted or adjacent to a missing hill. From the center of each plot, a 5 m^2 area was harvested for the determination of grain and straw yields at maturity. After harvest, grains were sun-dried, and weight and moisture content were measured. Grain yield was adjusted to 14% moisture content, and expressed in t ha^{-1}. Straw was also sun-dried and weighed. Sub-samples from the straw were taken and oven-dried at 70°C for 72 h and weight. Oven-dried weight of the straw was measured. Straw yield was adjusted to 3% moisture content, and expressed in t ha^{-1}. After counting of panicles from 12 hills, the average panicles $hill^{-1}$ was calculated. Based on average number of panicles $hill^{-1}$, two hills were selected to determine panicle length, grains per panicle and sterile spikelets $panicle^{-1}$. Panicle length was measured from the first neck to the top of the panicle. All the spikelets were separated manually from the sub-sampled panicles. Filled and unfilled spikelets were separated manually. Filled spikelets were oven-dried at 70°C to a constant weight for determination of the 1000-grain weight. Filled grains were counted by an electronic counter (Model 750, USA), while unfilled spikelets were counted manually. Percent of spikelet sterility was calculated using the formula:

$$\text{Spikelet sterility (\%)} = \frac{\text{Number of unfilled spikelets}}{\text{Total number of spikelets}} \times 100$$

Harvest index was computed as the ratio of grain yield and biological (grain + straw) yield (Fageria *et al.,* 2011), with the formula:

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

Data gathered in the experiments were statistically analyzed following procedures described by Gomez and Gomez (1984). Analysis of variance (ANOVA) was done using statistical software CropStat7.2. Means were compared with least significant difference (LSD) test.

RESULTS AND DISCUSSION

Effect of seedling age on yield, yield components, phenology and agronomic attributes

Seedling age had strong significant effect on grain yield at p=0.0002 and p=0.0023 probability level during 2010 and 2011 wet season (WS), respectively (Fig. 1 and 2). These findings are in conformity with Hussain *et al.,* 2012; Deb *et al.,* 2012; Sarwa *et al.,* 2011; Patra and Haque 2011; Bagheri *et al.,* 2011; Manjunatha *et al.,* 2010 and Faruk *et al.,* 2009. The highest yield was obtained in 14-d old seedling that was *at par* with 21-d old seedlings while the lowest was in 35-d old seedlings followed by 28-d old seedlings in both cropping years 2010 and 2011. Hussain *et al.* (2012) reported that overall higher yield was found after transplanting seedlings as young as 14-d compared to yields with 21, 28 and 35-d-old seedlings. In general, younger seedlings of 14 and 21-d old resulted in significantly higher yield than older seedlings of 28 and 35-d old (Hussain *et al.,* 2012; Sarwa *et al.,* 2011; Pasuquin *et al.,* 2008). Grain yield with 14-d old seedling was *at par* with 21-d old seedling; however, it was significantly higher than 28 and 35-d old seedlings. Grain yield fluctuated from 4.78 to 3.65 t ha^{-1} across the treatments 14-d old seedling to 35-d seedling. The magnitude of increase in the grain yield due to 14, 21 and 28-d old seedlings was 20.1, 18.4 and 10.8% over 35-d old seedlings for the year 2010 while the corresponding figures for the year 2011 were 23.6, 22.6 and 13.6% (Fig. 1 and 2). These findings are in good harmony with Hussain *et al.,* 2012 who reported that grain yield of 14, 21 and 28-d old seedlings was 14.3, 12.6 and 8% higher over the 35-d old seedlings. The cropping year 2010 was moderately rainy, while 2011 was with less rainfall. Since the experiments were conducted under rainfed condition, the rice cultivars produced higher yield during 2010 than 2011.

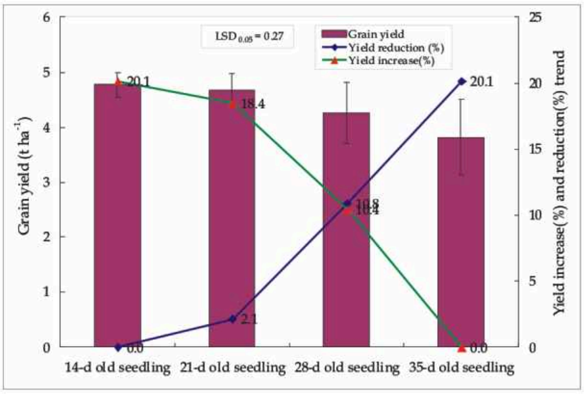

Fig. 1: Grain yield and its increase (%) trend from the lowest yield at 35-d old seedling and reduction (%) trend from the highest yield at 14-d old seedling during 2010.

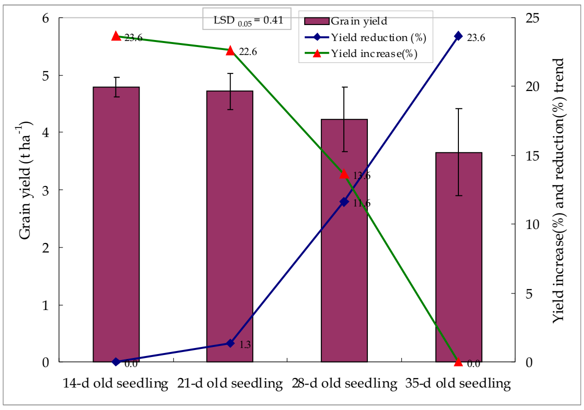

Fig. 2: Grain yield and its increase (%) trend from the lowest yield at 35-d old seedling and reduction (%) trend from the highest yield at 14-d old seedling during 2011.

Phenology, yield parameters and total biomass were significantly affected by the seedling age in both the cropping years 2010 and 2011 WS (Table 1 and Fig. 4). Seedling age had strong significant effect ($p<0.001$) on flowering, growth duration and plant height in both the cropping season (Table 1). The results are in alignment with the findings of Krishna and Patil (2009) and Karmakar *et al.* (2012). Irrespective of cultivars, the highest number of days (97 and 94 days) required for flowering in the 35-d old seedlings during 2010 and 2011, respectively. Days to flowering ranged from 82 to 97 days across the treatments from 14 to 35-d old seedlings. Krishna and Patil (2009) investigated that planting of younger seedlings (8-d) resulted in early flowering (91 days) as compared to 25-d old seedlings (95 days). In general, days required for flowering increased with increasing seedling age. Growth duration followed the similar trend of flowering, and maximum days (122 days) required when planted 35-d old seedling while the minimum days (110) for 14-d old seedlings. Plant height showed reverse trend of flowering and growth duration. The longest plant height found in the plant transplanted at 14-d old seedlings which was at par with 21-d old seedlings, and it reduced along with older seedling. Younger seedlings (14 and 21-d old) usually produced significantly taller plant than older seedlings (28 and 35-d old). The longest and the shortest plant height (108 and 103 cm) were found in 14 and 35-d old seedlings, respectively. These findings are supported by Hussain *et al.,* 2012 and; Mishra and Salokhe, 2008. Hussain *et al.* (2012) reported that the maximum plant height was recorded in the treatment with younger seedling (14-d), which is *at par*, with 21-d old, but significantly higher than with 28 and 35-d old seedlings which were again *at par* with each other. Mishra and Salokhe (2008) also recorded more plant height after transplanting younger seedlings (12-d), as compared to older (30-d) seedlings.

Yield components such as tillers and panicles m^{-2}, grains panicle^{-1}, spikelet sterility and grain weight were significantly affected ($p<0.001$) by seedling age in both cropping years (Table 1 and Fig. 4). Faghani *et al.* (2011) reported that seedling age had significant effect on total tiller number at 0.05 probability level. Tillers and panicle production per unit area were similar in planting 14 and 21-d old seedlings; however, it was significantly higher than 28 and 35-d old seedlings. These findings are in conformity with Hussain *et al.,* 2012; Sarwa *et al.,* 2011 and Krishna *et al.,* 2008. Sarwa *et al.,* (2011) reported that maximum tillers and panicles m^{-2} were recorded in transplanting of 10-d-old seedlings, followed by 20-d old seedlings, which was at par with 30-d old seedlings, while 40-d old seedlings produced the minimum tillers and panicles m^{-2}. Krishna *et al.* (2008) also reported that 12-d old seedlings produced more number of tillers and productive tillers m^{-2} compared to 25-d old seedlings. Both the tiller and panicle production were gradually declined with planting older seedlings. The results are in agreement with the findings of Hussain *et al.,* (2012) who reported that panicles m^{-2} registered a consistent decrease with the increase in seedling age from 14 to 35 days. Grains panicle^{-1} followed the similar trend of panicles m^{-2}. Grain production per panicle fluctuated 84 to 77 from 14 to 35-day old seedling. Ginigaddara and Ranamukhaarachchi (2011) reported that seedling age at transplanting had significant effects on grains per panicle. The highest number of grains panicle^{-1} (84) was produced 14-day old seedling which was statistically identical with transplanting 21-day old seedling. Hussain *et al.* (2012) concluded that grains panicle^{-1} depicted similar trends of panicle m^{-2} with regard to the seedling age. The lowest grains panicle^{-1} was in 35-day old seedling followed by 28-day old seedling (81). In contrast, spikelet sterility was statistically lower in 14 and 21-day old seedlings than 28 and 35-day old seedlings. Spikelet sterility ranged from 18.0 to 22.7% in 14 to 35-day old seedlings during 2010 while it was 18.6 to 23.1% during 2011, across the genotypes. In general, spikelet sterility was increased with increasing seedling age. Seedling age had significant effect on grain weight at p=0.0178 and p=0.0057 probability levels during 2010 and 2011, respectively (Table 1). Maximum 1000-grain weight was given by 14-d old seedlings (22.6 g), which was at par with 21-d old (22.5 g) and 28-d old (22.4 g) seedlings, but significantly higher than 35-d old seedling (22.2 g) during 2010. A similar trend for grain weight was recorded in 2011. Ginigaddara and Ranamukhaarachchi (2011) also reported that seedling age at transplanting had significant effects on weight of 1000-grains. Younger seedlings (14 and 21-d old) had higher grain weight compared to older seedlings (28 and 35-d old) for the wet season. The results are corroborating with the findings of Sarwa *et al.,* 2011; Hussain *et al.,* 2012 and Alam *et al.,* 2002. Quite the reverse, Faghani *et al.,* (2011) and Faruk *et al.* (2009) found that seedling age had no significant effect on grain weight.

Data pertaining to straw yield and total above ground biomass are presented in table 1, which shows that seedling age had significant effect on straw yield and total above ground biomass in both years at 0.05 and 0.01 probability levels, respectively. These results are in alignment with Sarwa *et al.,* 2011 and Hussain *et al.,* 2012. The highest straw yield belonged to the 14-day old seedling with an average of 4.78 t ha^{-1}, across the cropping season and genotypes. However, it was *at par* with 21 (4.72 t ha^{-1}) and 28-day old seedlings (4.47 t ha^{-1}) and statistically minimum straw yield was found in 35-d old seedlings. Hussain *et al.* (2012) also reported that younger seedlings of 14 and 21-d old produced *at par* straw yield but were superior to the 28 and 35-d old seedlings. Total above ground biomass production in planting with 14 and 28-d old seedlings were similar but it was significantly higher than 28 and 35-d old seedlings. In general, younger seedling had higher biomass compared to older seedlings. These results are corroborate with findings of Hussain *et al.* (2012) who as well reported that 14 and 21-d old seedlings accumulated significantly higher biomass compared to older seedling of 28 and 35-d old. In contrast, Alam *et al.* (2002) observed that seedling age had no significant effect on straw and biological yield.

Genotypic variation in yield, yield components, phenology and agronomic attributes

Significant variation (pd"0.001) observed among the cultivars in terms of grain yield during 2010 and 2011 (Fig. 3). These results are in harmony with Salem *at el.* (2011) who reported that cultivars had significant effect on yield across the seedling age. The genotypes IR83377-B-B-93-3 gave the highest mean grain yield (4.88 t ha^{-1}) which was statistically *at par* with IRRI 123 (4.82 t ha^{-1}) across the seedling age and cropping years. The lowest grain yield 3.73 t ha^{-1} was found in BRRI dhan57 followed by IR83381-B-B-6-1 (4.11 t ha^{-1}). BRRI dhan56 and Binadhan-7 yielded in between the highest and lowest. Overall the genotypes IR83377-B-B-93-3 surpassed to the other cultivars in respect yield and other parameters across the cropping years and seedling age. The genotypes showed significant diversity for days to flowering and maturity in both the cropping years (Table1). These findings are in alignment with Rai and Kushwaha (2008) and Karmakar *et al.* (2012). IRRI123 required the highest mean number of days (94 days) to flowering that was significantly higher compared to other genotypes across the years. In contrast, BRRI dhan57 took remarkably lowest mean number of days (82 days) for flowering. Days required to flowering fluctuated from 81 to 95 days among the genotypes across the seedling ages. Growth

Table 1: Effect of seedling age and genotype on phenology, agronomic attributes and yields of the rice genotypes during 2010 and 2011

Seedling age	Days to flowering	Days to maturity	Plant height (cm)	Tillers m^{-2} (No.)	Panicles m^{-2} (No.)	Grains $panicle^{-1}$ (No.)	Spikelet sterility (%)	1000-grain wt (g)	Total biomass (t ha^{-1})
Effect of seedling age									
Wet season 2010									
A_1	83	110	108	301	278	84	18.0	22.6	9.53
A_2	86	113	108	297	276	83	18.5	22.5	9.36
A_3	91	117	106	282	259	81	20.4	22.4	8.72
A_4	97	123	104	261	241	77	22.7	22.2	7.99
$LSD_{0.05}$	**1.0**	**0.9**	**0.8**	**17**	**11**	**3**	**1.9**	**0.2**	**0.55**
Wet season 2011									
A_1	82	110	108	301	301	84	18.6	22.6	9.59
A_2	85	113	107	299	299	84	18.9	22.5	9.47
A_3	89	117	105	278	278	81	20.8	22.3	8.70
A_4	94	121	103	257	257	77	23.1	22.0	7.78
$LSD_{0.05}$	**1.0**	**1.1**	**1.4**	**12**	**12**	**3**	**2.5**	**0.2**	**0.83**
Effect of genotype									
Wet season 2010									
V1	86	114	110	258	234	87	19.6	22.5	8.61
V2	83	109	100	305	281	72	22.0	19.6	8.10
V3	91	117	111	291	269	87	17.5	23.1	9.57
V4	95	122	110	309	288	82	18.1	22.9	9.67
V5	89	116	110	257	237	83	21.0	23.3	8.63
V6	90	118	98	291	272	77	21.0	23.0	8.81
$LSD_{0.05}$	**1.2**	**1.0**	**2.7**	**23**	**24**	**4**	**3.8**	**0.2**	**1.09**
Wet season 2011									
V1	84	113	110	257	257	87	19.2	22.7	8.68
V2	81	108	99	296	296	73	22.4	19.3	8.03
V3	88	117	111	291	291	87	17.7	23.0	9.64
V4	93	121	110	309	309	81	19.1	23.0	9.47
V5	88	116	108	259	259	81	22.8	23.1	8.55
V6	89	117	97	291	291	78	20.9	22.9	8.94
$LSD_{0.05}$	**0.7**	**0.9**	**1.6**	**13.5**	**14**	**2.9**	**2.3**	**0.3**	**0.71**

*Note: *Pd"0.05 (significant), **Pd"0.01 (highly significant), ***Pd"0.001 (strongly significant), ns=not significant.A_1=14-d old seedlings, A_2=21-d old seedlings, A_3=28-d old seedlings and A_4=35-d old seedlings.V_1=BRRIdhan56, V_2=BRRI dhan57, V_3=IR83377-B-B-93-3, V_4=IRRI123, V_5=IR83381-B-B-6-1 and V_6=Binadhan-7.*

duration of the rice genotypes followed the similar trend of flowering. Sha and Linscombe (2007) and Karmakar *et al.* (2012) have also observed similar results. Days required for maturity that means growth duration varied from 108 to 122 days among the genotypes across the seedling ages and cropping years. Plant height varied significantly ($p<0.001$) among the genotypes during 2010 and 2011. The mean highest plant height (110 cm) observed in BRRI dhan56 and IRRI 123 in both years while it was lowest (97 cm) in Binadhan-7 across the seedling ages and cropping years.

Genotypes had strong significant effect ($p<0.001$) on yield components such as tillers and panicles m^{-2}, grains panicle^{-1}, spikelet sterility and 1000-grain weight in both wet season 2010 and 2011 (Table 1). However sterility did not significantly affected by the genotypes in 2010. Similar findings also observed by Safdar *et al.* (2008), and Rai and Kushwaha (2008). The genotypes IRRI 123 gave the highest mean number of tillers and panicles m^{-2} (309 and 288) and the lowest (258 and 236) was in IR83381-B-B-6-1. In case of grains panicle^{-1}, it varied from 72 to 87 among the genotypes. IR83377-B-B-93-3 and BRRI dhan56 produced the highest number of grains panicle^{-1} while BRRI dhan57 gave the number of grains panicle^{-1}. Spikelet sterility was statistically identical in the genotypes IR83377-B-B-93-3, IRRI123, BRRI dhan56 Binadhan-7, however significantly higher sterility found in IR83381-B-B-6-1 and BRRI dhan57. Thousand grain weight of BRRI dhan57 was significantly lower than the other genotypes (Table 1). The result obtained agrees with the findings of Safdar *et al.* (2008). Total above ground biomass varied statistically (pd"0.05) among the genotypes. The highest mean biomass (9.61 t ha^{-1}) observed in IR83377-B-B-93-3 which at par with IRRI 123 (9.57 t ha^{-1}) and the lowest (8.07 t ha^{-1}) was in BRRI dhan57. Lack *et al.* (2012) also stated that there was a significant difference between cultivars regarding biological yield.

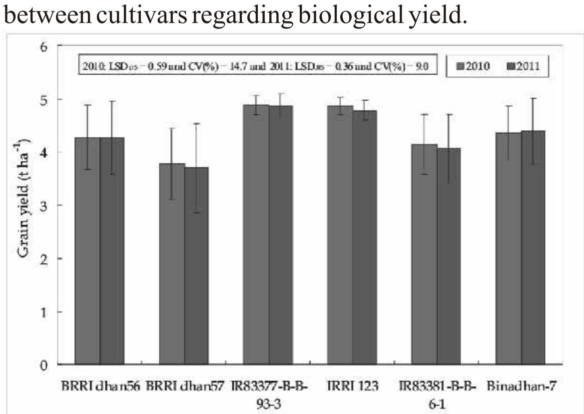

Fig. 3: Genotypic effect on grain yield at different seedling age during 2010 and 2011

Interaction effect of seedling age and genotype on yield, yield components, phenology and agronomic attributes

Interaction effect of seedling age and genotype was significant on grain yield, tillers and panicles m^{-2} during 2010 while it was statistically affected grain yield, tillers m^{-2} and total biomass during 2011 (Fig. 4 and 5; Table 2 and 3). Rest of the parameters differed considerably but remained insignificant. Among the genotypes, the highest grain yield (5.06 and 5.11 t ha^{-1}) was produced by IR83377-B-B-93-3 with 14 and 21-d old seedlings during 2010 and 2011, respectively. BRRI dhan56, BRRI dhan57, IR83381-B-B-6-1 and Binadhan-7 produced their highest grain yield with 14-d old seedlings which at par with 21-d old seedlings, however, it was significantly and steadily reduced when planted 28 and 35-d old seedlings (Fig. 4 and 5). In contrast, IRRI 123 produced the highest grain yield when planted 21-d old seedlings in 2010 that was *at par* with 14, 28 and 35-d old seedlings. But in 2011, IRRI 123 gave similar yield with 14 and 21-d old seedlings that did not significantly differed with 28 and 35-d old seedlings. The genotype IR83377-B-B-93-3 followed the similar trend of IRRI 123 in respect of grain yield. These findings are in conformity with those of Vange and Obi (2006), Lack *et al.* (2012) and Karmakar *et al.* (2012).

The phonological data such as days to flowering and maturity showed insignificant effect with the interaction of seedling age and genotype (Table 2 and 3). However, the genotypes exhibited remarkable variation regarding days required to flowering and maturity. Growth duration was the highest (130 days) in IRRI 123 with 35-d old seedlings while it was required only 115 days to get maturity with 14-d old seedlings across the genotypes and cropping years. Growth duration of BRRI dhan56 varied from 109 to 120 days and 108 to 118 days in 14-d old seedlings to 35-d old seedlings during 2010 and 2011, respectively. Similar trend of results were also observed for the other genotypes. Plant height usually was higher in 2010 than 2011 Plant height ranged from 92 to 113 cm and it was reduced by 5 to 8 cm from 14 to 35-d old seedlings across the genotypes and cropping years.

Interaction of seedling and genotype had significant effect on tillers and panicles m^{-2} at $p=0.0122$ and $p=0.0076$ level of significance, respectively during 2010 while it were at $p=0.0179$ and $p=0.0147$ level of significance, respectively during 2011 (Table 2 and 3). The highest number (333) of tillers m^{-2} was observed in the interaction of BRRI dhan57 and 14-d old seedling and the lowest (225) was in the interaction of IR83381-

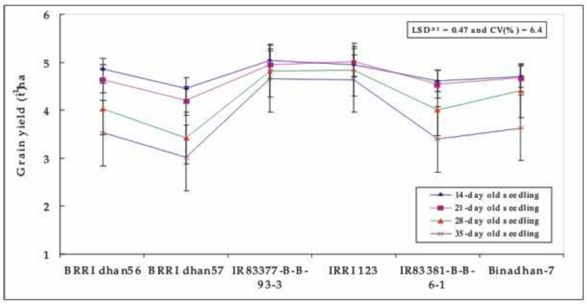

Fig.4: Interaction effect of seedling age and genotypes on grain yield of rice in 2010

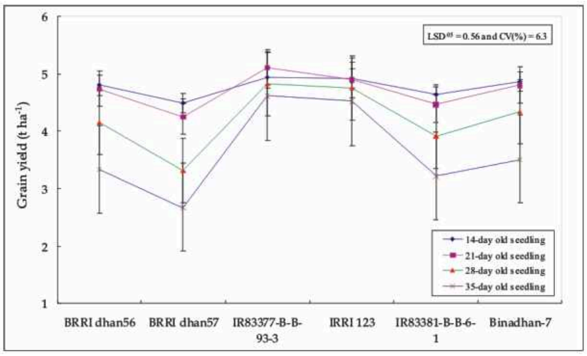

Fig.5: Interaction effect of seedling age and genotypes on grain yield of rice in 2011

B-B-6-1 and 35-d old seedling. On the contrary, the highest number of panicles m^{-2} was recorded in the interaction of IRRI 123 and 14-d old seedling rather than followed the similar trend of tillers m^{-2} (Table 2 and 3). Grains $panicle^{-1}$ ranged from 67 to 92 across the genotypes and seedling age. In most cases, highest value of tillers and panicles m^{-2} and grains $panicle^{-1}$ were found in 14-d old seedlings that was *at par* with 21-d old seedlings, subsequently reduced considerably. The highest number of grains $panicle^{-1}$ (92) obtained in the interaction of 14-d old seedling with BRRI dhan56 followed by the interaction of 14-d old seedling with IR83377-B-B-93-3 (88). In general, grains $panicle^{-1}$ reduced statistically along with increased seedling age for genotypes BRRI dhan56, BRRI dhan57, IR83381-B-B-6-1and Binadhan-7, however, it remained identical for the genotypes IR83377-B-B-93-3 and IRRI 123. Interaction of seedling age and genotype had no significant effect on spikelet sterility and 1000-grain weight during both the wet season of 2010 and 2011 (Table 2 and 3). However, sterility varied remarkably among the genotypes across the seedling ages. Sterility increased with increased seedling age. Sterility percentage was the highest (26.2%) observed in BRRI dhan57 with 35-d old seedling while it was the lowest (16.7%) in IR83377-B-B-93-3 with 14-d old seedling. These results are corroborating with the findings of Karmakar *et al.* (2012). The interaction of seedling age and genotype was insignificant effect on total above ground biomass during 2010, however. It had significant effect during 2011. The results are in agreement with the findings of Lack *et al.* (2012).

Seedling age was significantly affected grain yield across the genotypes during both the wet season of 2010 and 2011. Transplanting of 14 and 21-d old seedlings was statistically superior with regard to the grain yield as compared to 28 and 35-d old seedlings (Hussain *et al.,* 2012). Higher grain yield usually associated with younger seedlings (14 and 21-d old seedlings) rather than older seedlings (28 and 35-d old seedlings), which might be due to the increase in all yield attributes for the younger seedlings. On the other hand, grain yield was consistently reduced with older seedlings, which is associated with lower yield attributes (Sarwa *et al.,* 2011). The reduction in seed yield with 25-d old seedlings was attributed to the lower productive tillers per plant, as reported by Krishna and Patil (2009). Under rainfed environment, younger seedlings could able to mitigate the transplanting stress within a shorter period of time compared to that of older seedlings (Ginigaddara and Ranamukhaarachchi, 2011). Deb *at el.* (2012) reported that the early age of seedlings at transplantation seems to be consistently conducive to grain yield enhancement. Transplanting rice seedlings 20-d old has been commonly reported to generate an increase in grain yield as a result of higher tiller production (Pasuquin *et al.,* 2008). Across the cropping years and genotypes, mean grain yield were increased by 21.9, 20.5 and 12.2% in transplanting of 14, 21 and 28-d old seedlings over 35-d old seedlings. These findings concur with Hussain *et al.* (2012) who reported that grain yield of 14, 21 and 28-d old seedlings was increased by 14.3, 12.6 and 8.0% higher over the 35-d old seedlings. Similarly, mean yields were reduced by 1.7, 11.2 and 21.9% at 21, 28 and 35-d old seedlings compared to 14-d old seedlings. Patra and Haque (2011) reported that transplantation of 10-d old seedling gave 18.7% more grain yield than 18-d old seedlings. The results indicated that yield reduction in 21-d old seedling was very minimum, but increased the seedling age over 21-d decreased the yield drastically. It might be due to younger seedlings (14 and 21-d old seedlings) produced more panicles per unit area, higher number of grains $panicle^{-1}$ and less percentage of spikelet sterility compared to the older seedlings (28 and 35-d old seedlings). These findings are in conformity with

Table 2: Interaction effect between seedling age (A) and genotype (V) on phenology and agronomic attributes (2010)

Interaction V × A	Days to flowering	Days to maturity	Plant height (cm)	Tillers m^{-2} (No.)	Panicles m^{-2} (No.)	Grains $panicle^{-1}$ (No.)	Spikelet sterility (%)	1000-grain wt (g)	Total biomass (t ha^{-1})
V_1A_1	80	109	111	277	254	92	17.1	22.6	9.54
V_1A_2	83	112	111	274	252	90	18.2	22.5	9.09
V_1A_3	87	115	109	256	227	87	20.0	22.4	8.34
V_1A_4	93	120	107	224	205	82	23.3	22.4	7.49
V_2A_1	78	102	102	333	309	76	18.8	19.8	9.14
V_2A_2	80	106	101	324	302	76	20.0	19.7	8.82
V_2A_3	84	110	99	296	270	71	23.0	19.6	7.62
V_2A_4	91	116	97	265	241	67	26.2	19.4	6.80
V_3A_1	84	111	112	294	272	88	16.7	23.2	9.89
V_3A_2	87	115	112	293	271	87	16.9	23.2	9.71
V_3A_3	93	119	111	290	269	87	18.0	23.1	9.45
V_3A_4	100	125	111	287	266	86	18.4	23.0	9.25
V_4A_1	88	115	110	314	291	83	17.2	23.0	9.81
V_4A_2	93	119	110	312	292	83	17.1	23.1	9.96
V_4A_3	97	123	110	310	287	81	18.4	23.0	9.59
V_4A_4	103	131	109	301	282	79	19.7	22.8	9.33
V_5A_1	83	110	113	278	256	85	19.3	23.6	9.40
V_5A_2	86	113	112	276	255	85	19.6	23.5	9.26
V_5A_3	90	118	109	250	229	82	21.3	23.3	8.44
V_5A_4	97	123	106	225	206	79	23.8	23.0	7.42
V_6A_1	83	111	100	307	285	81	18.7	23.1	9.39
V_6A_2	87	115	100	305	284	80	19.0	23.1	9.30
V_6A_3	91	120	98	288	271	77	21.5	22.9	8.90
V_6A_4	98	125	96	264	245	71	24.7	22.8	7.64
$LSD_{(0.05)}$	**1.8**	**1.8**	**3.1**	**20.2**	**19.9**	**3.1**	**2.8**	**0.4**	**0.97**

Table 3: Interaction effect between seedling age (A) and genotype (V) on phenology and agronomic attributes (2011)

Interaction V × A	Days to flowering	Days to maturity	Plant height (cm)	Tillers m^{-2} (no.)	Panicles m^{-2} (no.)	Grains $panicle^{-1}$ (no.)	Spikelet sterility (%)	1000 grain wt (g)	Total biomass ($t\ ha^{-1}$)
$V_1 A_1$	79	108	111	277	256	90	17.7	22.8	9.57
$V_1 A_2$	82	111	110	274	255	89	18.1	22.8	9.46
$V_1 A_3$	86	114	110	251	232	87	18.9	22.7	8.51
$V_1 A_4$	90	118	109	226	207	83	22.2	22.5	7.18
$V_2 A_1$	76	102	103	325	305	77	19.4	20.0	9.46
$V_2 A_2$	79	105	101	318	297	76	20.0	19.7	9.01
$V_2 A_3$	83	109	97	285	263	72	23.5	19.2	7.45
$V_2 A_4$	88	114	95	256	236	67	26.8	18.6	6.20
$V_3 A_1$	84	113	113	294	270	88	17.3	23.2	9.73
$V_3 A_2$	86	115	112	297	274	89	16.8	23.2	9.96
$V_3 A_3$	89	118	111	291	268	87	18.0	23.0	9.57
$V_3 A_4$	92	121	111	283	261	86	18.8	22.8	9.30
$V_4 A_1$	87	116	111	318	288	82	18.3	23.1	9.72
$V_4 A_2$	91	119	110	316	287	83	18.5	23.0	9.65
$V_4 A_3$	95	123	110	306	282	81	19.5	23.0	9.47
$V_4 A_4$	100	128	109	297	274	80	20.0	22.9	9.04
$V_5 A_1$	82	111	111	281	258	85	19.6	23.4	9.35
$V_5 A_2$	85	114	110	277	254	84	20.7	23.3	9.15
$V_5 A_3$	90	118	107	252	228	80	23.9	23.0	8.42
$V_5 A_4$	95	122	104	226	204	75	26.9	22.6	7.28
$V_6 A_1$	83	112	100	312	291	81	19.3	23.1	9.71
$V_6 A_2$	86	115	99	310	285	82	19.3	23.0	9.58
$V_6 A_3$	91	118	96	285	263	78	21.1	23.0	8.79
$V_6 A_4$	96	123	92	255	236	73	24.0	22.7	7.70
$LSD_{(0.05)}$	**2.1**	**1.7**	**3.5**	**19.3**	**20.1**	**5.1**	**4.2**	**0.4**	**0.90**

Note : V_4=IRRI 123, V_5=IR83381-B-B-6-1 and V_6=Binadhan-7. A_1=14-d old seedlings, A_2=21-d old seedlings, A_3=28-d old seedlings and A_4=35-d old seedlings.

Hussain *et al.* (2012), Sarwa *et al.* (2011), Krishna *et al.* (2009), Pasuquin *et al.* (2008). On the contrary, Latif *et al.* (2005) concluded that seedling age ranging from just sprouted seed to 40-d old seedlings had no effect on grain yield, effective tillers m^{-2}; unfilled grains $panicle^{-1}$ and 1000-grain weight. Overall performance including yield was lower during the year 2011 compared to 2010 probably due to the crop of 2011 faced drought stress at reproductive phase for lower rainfall occurred in 2011. These results are in line with Sarwa *et al.* (2011) who also reported higher yield and overall better performance which might be due to the favorable weather condition for the rice crop. Interaction of seedling age and genotypes had significant effect of grain yield during both cropping years. All the tested genotypes gave highest grain yield at 14-d old seedlings that was at par with 21-d old seedlings during both cropping years. Among the genotypes, BRRI dhan56, BRRI dhan57 and IR83381-B-B-6-1 produced higher yield from 14 to 21-d old seedlings while Binadhan-7 gave at par yield from 14 to 28-d old seedling. A greater proportion of non-productive tillers and lower number of grains $panicle^{-1}$ in the genotypes BRRI dhan57 and IR83381-B-B-6-1 may result in grain yield reduction. In contrast, grain yield of IR83377-B-B-93-3 and IRRI 123 was statistically similar throughout the seedling age from 14 to 35-d old. It indicated these two genotypes have potentiality to produce higher yield even with older seedlings.

Phenological characteristics like flowering, maturity and plant height were significantly affected by seedling age and genotypes but the interaction effect of seedling age and genotype was insignificant. Days required to flowering and maturity remarkably increased with increasing seedling age. It was increased by 12 to 14 days at 14 to 35-d old seedlings. Similar observations of early flowering with younger seedlings were confirmed by Krishna *et al.* (2008). These were might be as a consequence of aged seedlings required more days to panicle initiation due to the slow establishment of the seedlings in the main field unlike the younger seedlings (Krishna and Patil, 2009). Younger seedlings (14 and 21-d old) usually produced taller plant compared to the older seedlings (28 and 35-d old) across the genotypes and cropping years (Hussain *et al.,* 2012; Mishra and Salokhe, 2008). This might be due to higher phyllocrone production in younger seedlings before entering to reproductive stage, as well as less transplanting shock at this stage (Hussain *et al.,* 2012). Plant height is an imperative yield trait that is controlled by the genetic makeup of the plant, as well as crop management practices (Hussain *et al.,* 2012).

Younger seedlings had statistically higher 1000-grain weight as compared to older seedlings (Sarwa *et al.,* 2011). This might be due to the transplanting of younger seedlings that enhanced more vegetative growth to contribute higher grain weight. The findings are also supported by Hussain *et al.* (2012), Sarwa *et al.* (2011), and Rao and Raju (1987) who reported that 1000-grain weight increased by transplanting younger seedlings as compared to older seedlings. Younger seedlings of 14 and 21-d old produced remarkably higher straw yield and biomass than older seedling of 28 and 35-d old because of higher tiller production (Hussain *et al.,* 2012).

It can be concluded that transplanting of younger seedlings at an age of 14 or 21-d produced at par grain yield, which was significantly higher than 28 and 35-d old seedlings. Interaction of seedling ages and genotypes showed that BRRI dhan56, BRRI dhan57, IR83381-B-B-6-1 and Binadhan-7 produced highest grain yield at 14-d old seedlings that was at par with 21-d old seedlings and thereafter yield significantly declined. In contrast, Binadhan-7 gave at par yield from 14 to 28-d old seedlings while the genotypes IR83377-B-B-93-3 and IRRI 123 gave at par yield from 14 to 35-d old seedling albeit the best yield obtained at 14-d old seedling. BRRI dhan56, BRRI dhan57 and IR83381-B-B-6-1 could be transplanted at 14 to 21-d old seedling while the other genotypes IR83377-B-B-93-3, IRRI 123 and Binadhan-7 could be transplanted 14-35-d old seedling to conquer better yield and performance.

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