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Effect of Pre-Planting Hardening of Seedlings on Growth, Dry Matter Accumulation and Tillering of Inbreed and Hybrid Rice

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Abstract

Introduction: The experiment was conducted to investigate the pre-planting hardening of seedling on the growth, dry matter accumulation and tillering of inbreed and hybrid rice.

Methods: The experiment was carried out with three varieties i.e. BRRI dhan53, BRRI hybriddhan4, and Pajam and five seedling hardening treatments viz. direct transplanting (T_1), storage in shade condition for 48 h (T_2), storage in open field condition for 48 h (T_3), storage in water condition for three days (T_4) and storage in cool air condition for 24 hours (T_5). This experiment was laid out in a randomized complete block design (factorial) with three replications.

Results: Results revealed that among the varieties BRRI hybriddhan provided maximum number of leaves, tillers, and accumulated highest amount of dry matter. On the other hand, Pajam exhibited the tallest plants at earlier growth stages. Among the hardening methods open field storage showed the best result.

Conclusions: Seedling hardening provides the rice seedlings better adaptability during its entire growth period and gives better yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal food crop of Bangladesh and it covers about 9.985 million hectares. The rice crop occupies a place in almost 98% of the existing number of cropping patterns of the country. It is the most important human food consumed by more than half of the world's population every day. In Asia, where 90% of rice is consumed, ensuring there is enough affordable rice for everyone, or rice security, is equivalent to food security [1]. Bangladesh is the fourth highest rice producing country in the world [2]. However, the country is now producing about 34.00 million tons to feed her 149.69 million people [3]. In such situation, there is no other alternative rather than development and adoption of yield enhancing technologies. To get higher productivity, hybrid rice is an important portion and readily available way as it has 20-30% yield advantage over inbred varieties [4].
Rice is extensively grown in three seasons of Bangladesh viz., Aus, Aman and Boro, which covers 80% of the total cultivable area [5]. Aman rice holds the major share of acreage [6]. The unexpected environmental condition causes serious damage to the rice seedlings in the nursery beds and in the freshly transplanted fields. Under this situation, the rice seedlings may be saved by uprooting them from the nursery beds. Though aman rice production is increasing day by day but the demand of aman rice cannot satisfy due to lack of high seedling vigority during uprooted rice seedling. Crop damage due to early or late flooded is very common in Bangladesh, in flood prone areas, farmers cannot retransplant the affected land due to unavailability of seedlings. In this case seedlings are often stored under different conditions. In many reports , storage in seedling under adverse condition showed higher vigority and yield performance under field condition. Seed and seedlings both are undergone this condition which are termed as priming and hardening, respectively.
The term, hardening off, refers to the process of gradually exposing seedlings that have been raised in protective covering system to the climatic condition they will be grown in. This is done to reduce stress and subsequent growth check when seedlings are transplanted to the main garden [7]. Although this methods are widely practiced in vegetables few studies have been conducted on the effect of seedling hardening on

the performance of cereal crops like rice, wheat and maize. For example, cold hardening treatments have some beneficial effects on metabolic and physiological processes of plant which improves the cold tolerance in different crops [8-12]. The underlying mechanism(s) how seedling hardening can enhance the growth and productivity of transplanted crops may be their cross-adaptation process. There are few hypotheses have been proposed to elucidate it; most are based on roles of H_2O_2, antioxidants (glutathione and ascorbic acid and heat shock proteins [13-17]. Later on, Chao and Kao [15] showed that heat-shock (45 °C, 3 h) induced accumulation in leaves induces stress tolerance. Heat-shock induced stress-tolerance rice seedlings were also found to be associated with higher APX and GR activities [18]. Ferreira-Silva et al. [16] showed that high temperature positively modulates oxidative protection in salt-stressed cashew (*Anacardium occidentale*) plant by the activation of antioxidant enzymes such as SOD, APX, CAT as well as favorable changes in the ascorbate redox state. Seedlings that underwent hardening increased their total sugar and α-amylase activity and exhibited earlier initiation of protein, RNA, and DNA synthetic activity. Consequently, when the seedling is set out for establishment, cellular events are much advanced [19]. Considering the above facts it is hypothesized that the short-term adverse condition of seedling just before transplanting may induce the upregulation of defense mechanisms in plants which would be active during the subsequent episodes after transplantion to provide healthy plants with better productivity of rice seedlings.

It is an urgent need of the time to increase rice production through increasing the yield. Proper planting and management practices are the most effective means for increasing yield of aman rice at farmers level using inbred and hybrid varieties [20]. Thus a detailed study with an inbreed and a hybrid variety with some pre planting hardening of seedling treatment were undertaken to investigate the effect on the performance of aman rice as well as to compare the relative performance of local, HYV and hybrid rice under different hardening treatment.

METHODS

Experimental Location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 (23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above sea level). The soil of the experimental site belongs to the Shallow Red Brown Terrace Soils. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranges from 5.4-5.6 and had organic carbon 0.82%. The experimental area was flat having available irrigation and drainage system and above flood level.

Experimental Treatments and Design

Rice cv. BRRI dhan53, BRRI hybriddhan4, and Pajam were used as plant materials for the present study which were collected from Bangladesh Rice Research Institute, Gazipur, Bangladesh. There were four hardening treatments viz. T_1 = Direct transplanting, T_2 = Storage in shed, T_3 =Storage in open field, T_4 = Storage in water and T_5 =Storage in cool air. For open field hardening, uprooted seedlings were tied in bundle and placed upright under ambient condition with direct sunlight for 48 h. For cold hardening the uprooted seedlings were tied in bundles and kept in cold temperature (4°C) in refrigerator for 24 h. For water hardening, uprooted seedlings were kept under water for 48 h. For shade hardening, uprooted seedlings were kept in shade for 48 h. The experiment was laid out in randomized complete block design (RCBD) with three replications.

Crop Husbandry

The experimental field was first opened with the help of a tractor drawn disc plough, later on the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor plough and subsequently leveled by laddering. The experimental area was fertilized with 120, 80, 80, and 20 kg ha^{-1} N, P_2O_5, K_2O, and S applied in the form of urea, triple super-phosphate (TSP), murate of potash (MOP), and gypsum respectively. The entire amounts of TSP, MOP, and gypsum were applied as basal dose at final land preparation. Urea was top-dressed in three equal installments. Urea was top dressed in three equal splits on final land preparation, 30, and 50 DAT. The seedbeds were made wet by the application of water both in the morning and evening on the previous day before uprooting for treatment. The seedlings were then uprooted carefully to minimize mechanical injury to the roots and kept on soft mud in shade, in open field and in water for 3 d and in cold temperature for 1 d before they were transplanted. The 25-d-old seedlings were transplanted on the well puddle experimental plots by considering two seedlings $hill^{-1}$. All other intercultural operations were done whenever necessary.

Data Collection

Experimental data were recorded from 30 days of growth duration and continued until harvest. Dry weights of plant were collected by harvesting respective number of hills at different dates from the inner rows leaving border rows and harvest area for grain.

Statistical Analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factor analysis of variance (ANOVA) with the help of computer package XL-STAT 2014 and mean separation will be done by LSD at 5% level of significance.

RESULT

Plant Height

Plant height of different inbreeds and hybrid varieties of transplanted aman rice was significantly different (Fig 1). The tallest plants were found from the variety BRRI hybriddhan4 (118.00 cm), which was significantly differed from the other varieties. The lowest plant height was observed in the variety BRRI dhan53 and Pajam. At 30 DAT, Pajam produced the tallest plants (64.63 cm) while the shortest plantheight (54.03 cm) was observed from BRRI dhan53 which is statistically similar with BRRI hybriddhan4. At 45 DAT, BRRI hybriddhan4 produced the tallest plants (80.23 cm) which was statistically similar (78.83 cm) with Pajam and BRRI dhan53 was recorded the shortest plants (60.80 cm). At 60 DAT, the tallest plant (91.30 cm) was observed in BRRI hybrid dhan4 and Pajam whereas the shortest plant (74.20 cm) was recorded from BRRI dhan53. At 75 DAT and at harvest, the tallest plant was recorded from BRRI hybriddhan4 and the shortest plant was recorded from BRRI dhan53 and Pajam. The plant height was varied mainly due to its genetic characters and thus the differences were observed in such cases.

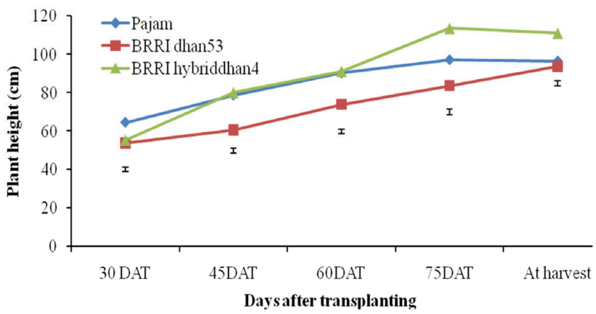

Figure 1: Effect of Varieties on Plant Height of Transplanted Rice at Different Growth Stages. Vertical Bars Indicate the LSD Values.

Significant variation of plant height was found due to different seedling hardening treatments in all the studied durations (Table 1). The results revealed that at 30 DAT, the tallest plant (72.19 cm) was obtained from the T_3 and the shortest plant (58.05 cm) was obtained from the direct transplanting. The tallest plant (94.24 cm) was recorded at 45 DAT from T_3 followed by T_5 (87.89 cm) and T_2 (82.21 cm) and the shortest plant was obtained from the direct transplanting (73.29 cm). At 60 DAT the tallest plant was observed from T_3 (105.62 cm) and the shortest plant was obtained from the direct transplanting (85.26 cm). At harvest, the tallest plant (117.29 cm) was obtained from T_3 and the shortest plant was obtained from T_1 (100.52 cm). Significant interaction effect between the variety and hardening of seedling on plant height was observed at 30, 45, 60 and 75 DAT and at harvest (Table 2). The results revealed that at 30 DAT, the tallest plant (76.77 cm) was obtained from the T_3 of the variety pajam which was statistically similar with the T_3 of the BRRI dhan53 variety (76.50 cm) and the shortest plant (54.03 cm) was obtained from the direct transplanting seedlings of the BRRI dhan53 variety which was statistically similar with the V_3T_4, V_3T_2, V_2T_4 and V_3T_1. The tallest plant (99.13 cm) was recorded at 45 DAT from T_3 of BRRI hybriddhan4 which was statistically similar with the T_3 (98.33 cm) of Pajam variety and the shortest plant (60.80 cm) was obtained from the direct transplanting seedlings of BRRI dhan53. At 60 DAT the tallest plant was observed from T_3 (115.17 cm) of BRRI hybriddhan4 variety which was statistically similar with T_5 (112.23 cm) of BRRI hybriddhan4 variety and the shortest plant (74.20 cm) was obtained from the direct transplanting seedlings of BRRI dhan53 variety which was statistically similar with the storage in water treatment (77.13 cm) of BRRI dhan53 variety. At 75 DAT the tallest plant was observed from T_3 (127.27 cm) in BRRI hybriddhan4 variety which was statistically similar with T_5 (121.93 cm) in BRRI hybriddhan4 variety and the shortest plant (83.90 cm) was obtained from the direct transplanting seedlings of BRRI dhan53 which was statistically similar with the storage in water treatment (86.83 cm) of BRRI dhan53 variety. At harvest, the tallest plant (128.87 cm) was obtained from observed from T_3 (128.87 cm) of BRRI hybriddhan4 variety which was statistically similar with T_5 (123.90 cm) of BRRI hybriddhan4 variety and the shortest plant (94.00 cm) was obtained from the direct transplanting seedlings of BRRI dhan53 variety which was statistically similar with V_2T_4 (96.87 cm), V_1T_4 (96.73 cm) and V_1T_1 (96.47 cm).

Table 1: Effect of Seedling Hardening Treatment on Plant Height at Different Growth Duration of Transplanted Rice

Treatments	**Plant Height (cm) at**				
	30 DAT	**45 DAT**	**DAT 60**	**75 DAT**	**At Harvest**
T_1	58.06d	73.29d	85.26e	98.23d	100.52d
T_2	62.41c	82.21c	95.20c	103.06c	105.38b
T_3	72.19a	94.24a	105.62a	113.19a	117.29a
T_4	59.32cd	76.73d	88.37d	101.31cd	102.09cd
T_5	66.18b	87.89b	99.82b	108.51b	112.88b
$LSD_{(0.05)}$	3.25	3.47	3.07	3.75	3.41
CV (%)	5.29	4.33	3.35	3.70	3.28

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 =Storage in open field, T_4 = Storage in water, T_5 =Storage in cool air

Table 2: Combined Effects of Variety and Treatments on Plant Height of Transplanted Rice at Different DAT					
Variety x Treatment	**Plant Height (cm) at**				
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**At harvest**
Pajam (V_1)					
T_1	64.63b-e	78.83g	90.27e	97.17h	96.47fg
T_2	66.40b-d	85.80c-e	97.37d	100.17f-h	100.37ef
T_3	76.77a	98.33a	102.70c	108.50de	108.73cd
T_4	61.17d-g	79.73fg	89.67e	96.50hi	96.73fg
T_5	69.53b	89.90cd	99.53cd	105.57ef	105.70de
BRRI dhan53 (V_2)					
T_1	54.03i	60.80i	74.20g	83.90k	94.00g
T_2	62.70d-g	69.17h	80.13f	90.47ij	100.23ef
T_3	76.47a	85.27d-f	99.00cd	103.80e-g	114.27bc
T_4	57.20g-i	66.83h	77.13fg	86.83jk	96.87fg
T_5	68.43bc	77.67g	87.70e	98.03gh	109.03cd
BRRI hybriddhan4 (V3)					
T_1	55.50hi	80.23e-g	91.30e	113.63cd	111.09b-d
T_2	58.13f-i	91.67bc	108.10b	118.53bc	115.55b
T_3	63.33c-f	99.13a	115.17a	127.27a	128.87a
T_4	59.60e-i	83.63e-g	98.30cd	120.60b	112.67bc
T_5	60.57e-h	96.10ab	112.23ab	121.93ab	123.90a
$LSD_{(0.05)}$	5.63	6.00	5.32	6.49	5.90
CV (%)	5.29	4.33	3.35	3.70	3.28

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 =Storage in open field, T_4 = Storage in water, T_5 =Storage in cool air.

Table 3: Effect of Seedling Hardening Treatment on Number of Tillers $Hill^{-1}$ at Different Growth Duration of Transplanted Rice				
Treatments	**Number of Tillers $Hill^{-1}$ at Different DAT**			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
T_1	9.60d	9.09e	11.60d	12.26c
T_2	11.02b	10.73c	12.97c	14.03b
T_3	11.88a	13.39a	15.56a	15.54a
T_4	10.32c	9.93d	12.40cd	12.77c
T_5	11.39ab	12.42b	15.04b	14.70ab
$LSD_{(0.05)}$	0.56	0.60	0.85	0.86
CV (%)	5.42	5.62	5.62	6.46

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 =Storage in open field, T_4 = Storage in water, T_5 =Storage in cool air

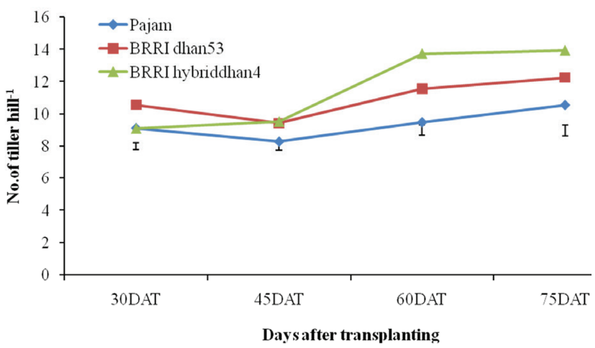

Figure 2: Effect of Variety on Tillers $Hill^{-1}$ of Transplanted Rice at Different Days after Transplanting. Vertical Bars Indicate the LSD Values.

Number of Tillers $Hill^{-1}$

Varietal variation had significant effect on tillers $hill^{-1}$ over time except at 75 DAT (Fig 2). Total tillers $hill^{-1}$ increased up to 60 DAT and then remain same up to harvest among all the varieties. BRRI hybrid dhan4 showed the highest number of tillers $hill^{-1}$ (9.53, 13.73 and 13.93 at 45, 60 and 75 DAT respectively) throughout the growing period except at 30 DAT. BRRI hybriddhan4 was recorded the highest tillers $hill^{-1}$ (13.93) at 60 DAT. The lowest tillers $hill^{-1}$ (10.57 cm) was recorded from Pajam.

The total number of tillers $hill^{-1}$ was significantly influenced by different hardening treatments at 30, 45, 60 and 75 DAT (Table 3). At 30 DAT the highest numbers of tillers $hill^{-1}$ was observed in T_3 (11.88) which were statistically similar with

T_5 (11.39). The highest number of tillers hill-1 (13.89) at 45 DAT was observed in T_3 and the lowest numbers of tillers hill-1 was obtained from direct transplanting treatment (9.09). At 60 DAT highest numbers of tillers hill-1 was observed in open in shade (15.96) and the lowest numbers of tillers hill-1 was obtained from T_1 (11.6) which was statistically similar with storage in water treatments. At 75 DAT highest numbers of tillers hill-1 was observed in open in shade (15.54) and the lowest numbers of tillers hill-1 was obtained from T_1 (12.25) which was statistically similar with storage in water treatments (12.77).

The interaction effect of seedling hardening treatments and variety significantly influenced the number of tillers hill-1 at different DAT (Table 4). At 30 DAT, highest number of tillers hill-1 (13.73) was recorded from the combinations of BRRI dhan53 and Open field storage treatments. Treatment combinations of BRRI hybriddhan4 and storage in open field treatments was recorded the highest number of tillers hill-1 (13.73, 18.30 and 17.70) at 45, 60 and at 75 DAT respectively and combinations of BRRI hybriddhan4 and cold storage condition scored second highest (16.87) at 75 DAT. The lowest number of tillers hill-1 was recorded from the treatment combinations associated with no treatments that or direct transplanting throughout the growing period.

Number of Leaves Hill-1

Numerically maximum number of leaves hill-1 at 30, 45, 60 and 75 DAT was observed in BRRI hybriddhan4 and the minimum number of leaves hill-1 was obtained from the local variety Pajam.

Table 4: Combined Effect of Variety and Treatments on Number of Tillers Hill-1 of Transplanted Rice at Different DAT

Variety x Treatment	Number of Tillers Hill-1 at			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
Pajam (V_1)				
T_1	9.13g	8.300h	9.500j	10.57i
T_2	9.07g	10.30fg	11.167i	13.43efg
T_3	10.27ef	12.93ab	13.00fgh	13.63efg
T_4	9.10g	9.47g	10.53ij	11.37hi
T_5	9.47fg	11.83cd	11.80ghi	13.13efg
BRRI dhan53 (V_2)	10.57e	9.43g	11.57hi	12.27gh
T_1				
T_2	13.20ab	10.53ef	13.07fg	12.67fgh
T_3	13.73a	13.50ab	16.57bc	15.30cd
T_4	12.37bc	10.13fg	13.23efg	12.37gh
T_5	13.47a	12.57bc	15.73cd	14.10def
BRRI hybriddhan4 (V_3)	9.10g	9.533fg	13.73ef	13.93def
T_1				
T_2	10.80de	11.37de	14.67de	16.00bc
T_3	11.63cd	99.13a	115.17a	127.27a
T_4	9.50fg	83.63e-g	98.30cd	120.60b
T_5	11.23de	96.10ab	112.23ab	121.93ab
$LSD_{(0.05)}$	0.98	1.04	1.47	1.49
CV (%)	5.42	5.62	6.49	6.46

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

Table 5: Effect of Seedling Hardening Treatment on Number of Leaves Hill-1 at Different Growth Duration of Transplanted Rice

Treatments	Number of Leaves Hill-1 at Different DAT			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
T_1	55.32d	60.37c	72.44c	76.52d
T_2	60.44bc	65.48b	76.90b	80.82bc
T_3	65.04a	68.39a	83.20a	86.31a
T_4	59.06c	63.52b	75.37b	79.23c
T_5	61.27b	65.48b	77.10b	81.49b
$LSD_{(0.05)}$	1.90	2.59	2.39	2.01
CV (%)	3.27	4.15	3.22	2.59

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

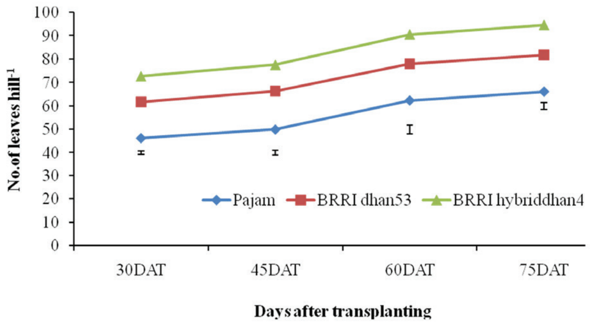

Figure 3: Effect of Variety on Number of Leaves Hill^{-1} at Different Days after Transplanting on Rice. Vertical Bars Indicate the LSD Values.

The total number of leaves hill^{-1} was significantly influenced by different seedling hardening treatment at 30, 45, 60 and 75 DAT but (Table 5). At 30 DAT highest number of leaves hill^{-1} was observed in T_3 (65.04). The highest number of leaves hill^{-1} (68.39) at 45 DAT was observed in T_3 and the lowest number of leaves hill^{-1} was obtained from direct transplanting seedlings (60.37). At 60 DAT highest numbers of tiller hill^{-1} was observed in storage in open field treatment (83.20) and the lowest numbers of leaves hill^{-1} was obtained from T_1 (72.24). At 75 DAT highest numbers of tiller hill^{-1} was observed in storage in open field treatment (86.31) and the lowest numbers of leaves hill^{-1} was obtained from T_1 (76.52). Significant interaction effect between the variety and hardening treatment on number of leaves hill^{-1} was observed at 30, 45, 60 and 75 DAT (Table 6). The results revealed that at 30 DAT, the highest number of leaves hill^{-1} was observed in T_3 (75.20) of the BRRI hybriddhan4 which was statistically similar with T_2 (73.53), T_5 (72.37), T_4 (72.17) of same variety. At 45 DAT highest number of leaves hill^{-1} were obtained from T_3 (78.83) of BRRI hybriddhan4 variety which was statistically similar with T_2 (78.27), T_5 (78.03), T_4 (76.80) and T_1 (75.87). Highest number of leaves hill^{-1} at 60 DAT was observed in T_3 (97.93) of the BRRI hybriddhan4. At 75 DAT highest number of leaves hill^{-1} were obtained from T_3 (100.43) of BRRI hybriddhan4 variety followed by other treatments of seedling hardening.

Leaf Area Index (LAI)

Varietal effect significantly influenced leaf area index (LAI) of aman rice at 30, 45, 60 and 75 DAT (Fig 4). At 30 DAT, 45 DAT and 60 DAT, the higher leaf area index was found in the hybrid variety BRRI hybriddhan4 and the lower leaf area index was found in the local variety Pajam. This might be due to the production of comparatively lower tillers of the local variety than the inbred variety which consequently decreased the number of leaves plant^{-1} and leaf area index.

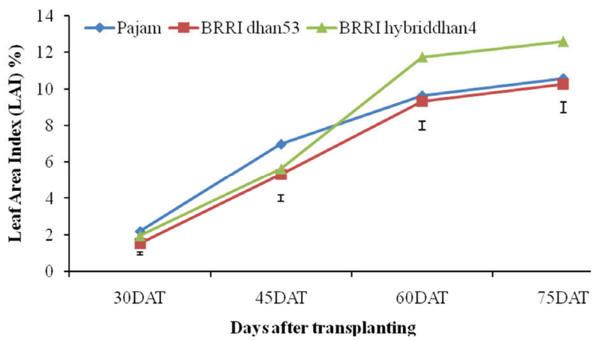

Figure 4: Effect of Variety on Leaf Area Index at Different Growth Duration of Transplanted Rice. Vertical Bars Indicate the LSD Values.

Table 6: Combined Effects of Variety and Treatments on Number of Leaves Hill^{-1} of Transplanted Rice at Different DAT

Variety x Treatment	Number of Leaves Hill^{-1} at			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
Pajam (V_1)				
T_1	41.63cd	56.13cd	60.77cd	60.43c
T_2	45.13bc	59.20bc	64.10b	65.20b
T_3	49.87a	64.43a	68.96a	68.33a
T_4	41.40d	52.77d	60.00d	60.33c
T_5	48.60ab	58.56bc	63.50bc	63.77b
BRRI dhan53 (V_2)				
T_1	29.43g	36.93f	39.50g	39.97f
T_2	30.63g	37.80f	40.67g	41.40f
T_3	35.03ef	45.03e	50.03e	50.23d
T_4	29.56g	38.63f	41.47g	42.33f
T_5	31.83fg	44.17e	46.47f	46.80e
BRRI hybriddhan4 (V_3)				
T_1	38.53de	47.53e	49.23ef	49.83de
T_2	45.13bc	57.03bc	59.40d	59.90c
T_3	47.87ab	60.17b	64.57b	64.87b
T_4	38.83d	47.30e	49.10ef	49.57de
T_5	46.83ab	60.30b	64.17b	64.63b
$LSD_{(0.05)}$	3.29	4.48	4.15	3.49
CV (%)	3.27	4.15	3.22	2.59

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

Seedling hardening treatment significantly influenced Leaf area index (LAI) of aman rice was at 30, 45, 60 and 75 DAT (Table 7). At 30 DAT, storage in open field T_3 produced the highest leaf area index (2.27) which was statistically similar with T_5 (2.16) and direct transplanting seedlings produced the lowest leaf area index (1.60). At 45 DAT highest leaves area index (6.78) was observed in T_3 and the lowest was observed in direct transplanting seedlings (5.33). This might be due to higher leaf number in storage in open field treatment at early growth stage of rice plant. Highest leaf area index (11.93) at 60 DAT was obtained from T_3 and the lowest leaf area index (8.40) was observed in T_1. At 75 DAT T_3 produced highest leaf area index (12.81) and the lowest leaf area index (9.40) was observed in T_1 which was statistically similar with T_4 (10.04).

Interaction effect of variety and seedling hardening treatment significantly influenced leaf area index (LAI) of aman rice at 30, 45, 60 and 75 DAT (Table 8). At 30 DAT, V_1T_3 produced the highest leaf area index (2.9) which is statistically similar with V_1T_5 (2.67) and the lowest LAI was observed in V_2T_4 (1.33) which is statistically similar with V_2T_1 (1.37), V_2T_2 (1.44) and V_1T_1 (1.60). At 45 DAT the highest LAI was obtained from V_1T_3 (7.73) which was statistically similar with V_1T_5 (7.43) and V_1T_2 (7.03) and the lowest LAI was observed in V_3T_1 (4.63) which was statistically similar with V_2T_4 (4.97), V_2T_1 (5.10), V_2T_2 (5.17), and V_3T_2 (5.19). Highest LAI at 60 DAT was observed in V_3T_3 (13.63) which was statistically similar with V_3T_5 (12.57) and the lowest LAI was observed in V_2T_1 (7.83) which was statistically similar with V_1T_1 (7.97), V_2T_4 (8.33), and V_1T_4 (8.47). At 75 DAT highest LAI (14.30) was obtained from V_3T_3 which was statistically similar with V_3T_5 (13.60) and V_3T_2 (13.03) and the lowest LAI (8.70) was obtained from V_2T_1 which was statistically similar with V_2T_4 (9.10), V_1T_1 (9.10), V_1T_4 (9.40).

Table 7: Effect of Seedling Hardening Treatment on Leaf Area Index at Different Growth Duration of Transplanted Rice

Treatments	**Leaf Area Index at**			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
T_1	1.60c	5.33d	8.40d	9.40c
T_2	1.80b	5.76c	10.48b	11.49b
T_3	2.27a	6.78a	11.93a	12.81a
T_4	1.64c	5.68cd	9.21c	10.04c
T_5	2.16a	6.27b	11.08b	11.92b
$LSD_{(0.05)}$	0.18	0.43	0.64	0.75
CV (%)	9.86	7.52	6.46	7.00

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

Table 8: Combined Effect of Variety and Treatments on Leaf Area Index (LAI) of Transplanted Rice at Different DAT

Variety Treatment	**Leaf Area Index (LAI) at**			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
Pajam (V_1)				
T_1	1.60e-h	6.27d-f	7.967i	9.10hi
T_2	2.10b	7.03a-c	9.50e-g	10.60e-g
T_3	2.90a	7.73a	11.63bc	12.37b-d
T_4	1.67d-g	6.37c-e	8.47g-i	9.40g-i
T_5	2.67a	7.43ab	10.50d-f	11.23d-f
BRRI dhan53 (V_2)				
T_1	1.37gh	5.10h-j	7.83i	8.70i
T_2	1.40f-h	5.17g-j	9.70ef	10.53e-g
T_3	1.83b-e	5.33e-h	10.53c-e	11.73c-e
T_4	1.33h	4.967ij	8.33hi	9.10hi
T_5	1.73cd-f	5.57f-i	10.17d-f	11.14d-f
BRRI hybriddhan4 (V_3)				
T_1	1.83b-e	4.63j	9.40f-h	10.40f-h
T_2	1.90bc	5.17g-j	12.23b	13.03a-c
T_3	2.07b	6.77b-d	13.63a	14.30a
T_4	1.93b-d	5.60e-i	10.83cd	11.63d-f
T_5	1.97b-d	5.80e-g	12.57ab	13.60ab
$LSD_{(0.05)}$	0.43	0.75	1.10	1.30
CV (%)	9.86	7.52	6.46	7.00

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

Dry Matter Production

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. TDM of roots, leaves, leaf sheath + stem and or panicles of all varieties were measured at 30, 45, 60 and at 75 DAT. It was evident from Fig.5 that irrespective of treatments TDM of all the varieties significantly varied at all sampling dates. Here Pajam achieved the highest dry matter throughout the growing period (4.45, 13.34 and 14.92 g $hill^{-1}$ at 30, 45, 60 DAT respectively except at 75 DAT). Lower amount of dry matter production was observed in BRRI dhan53 and BRRI hybriddhan4 throughout the growing period except at 75 DAT. This may be due to the highest number of tiller mortality. Main et al. [21] also observed that hybrid rice produced more dry matter in plant than inbred varieties.

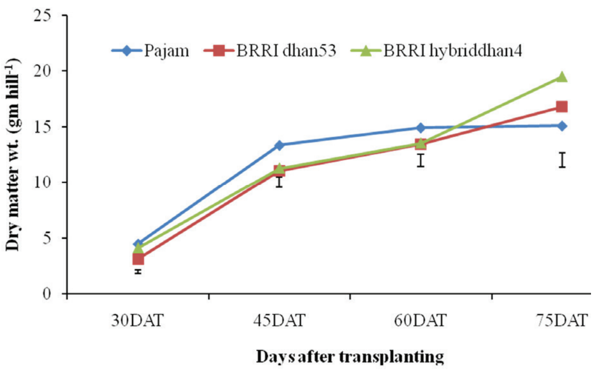

Figure 5: Effect of Variety on Total Dry Matter Production of Transplanted Rice at Different Days after Transplanting. Vertical Bars Indicate the LSD Values.

Total dry matter (TDM) increased exponentially with time. TDM was significantly affected by different treatments (Table 9). From the early stages distinct differences were visible among the treatments in TDM production. The lowest TDM throughout the growing period was observed in direct transplanting and storage in shade treatment. All of the treatments gave statistically similar results from 15 to 75 DAT. Among all the treatments, Storage in open field achieved the highest TDM throughout the growing period. Significant interaction effect between the variety and seedling hardening treatments on dry matter production (g $hill^{-1}$) was observed at 30, 45, 60 and 75 DAT and (Table 10). The results revealed that at 30 DAT, the highest dry weight was observed in T_3 (5.2 g $hill^{-1}$) of the local variety (V_1) and the lowest in direct seedling treatment condition (2.63 g $hill^{-1}$) of the inbred variety (V_2) which was statistically similar with the storage in shade condition (2.97 g $hill^{-1}$), storage in water (2.97 g $hill^{-1}$) and storage in cool air treatment (3.17 g $hill^{-1}$) of the inbred variety (V_2). At 45 DAT the highest dry weight were obtained from T_3 (15.42 g $hill^{-1}$) of the local variety (V_1) which was statistically similar with T_5 (14.467 g $hill^{-1}$) of local variety (V1), V_2T_3 (14.20 g $hill^{-1}$), V_3T_3 (13.73 g $hill^{-1}$) and V_1T_2 (13.59 g $hill^{-1}$) and the lowest from direct transplanting seedlings (9.107 g $hill^{-1}$) of the inbred variety (V_2) which was statistically similar with the direct transplanting seedlings (79.27 g $hill^{-1}$) which is statistically similar with V_2T_4 (9.27 g $hill^{-1}$), V_3T_4 (9.63 g $hill^{-1}$), V_2T_2 (10.33 g $hill^{-1}$), V_1T_1 (10.63 g $hill^{-1}$), V_3T_2 (10.76 g hill-1). At 60 DAT the highest dry weight was observed in T_3 (18.43 g $hill^{-1}$) of the local variety (V_1) variety and the lowest in T_4 (11.43 g $hill^{-1}$) of the inbred variety (V_2) which was statistically similar with direct transplanting seedlings (11.77 g $hill^{-1}$) of inbred, (12.30 g $hill^{-1}$) hybrid and local (12.7 g $hill^{-1}$) variety and V_3T_4 (12.73 g $hill^{-1}$), V_2T_2 (13.17 g $hill^{-1}$), V_3T_2 (13.37 g $hill^{-1}$), V_1T_4 (13.73 g $hill^{-1}$). At 75 DAT the highest dry weight was observed in T_3 (21.10 g $hill^{-1}$) of the hybrid variety (V_3) variety which is statistically similar with V_2T_3 (20.47 g $hill^{-1}$), V_3T_5 (20.30 g $hill^{-1}$), V_3T_2 (19.30 g $hill^{-1}$), V_3T_4 (18.90 g $hill^{-1}$), V_1T_3 (18.70 g $hill^{-1}$) and the lowest in T_1 (12.87 g $hill^{-1}$) of the local variety (V_1) which was statistically similar with V_1T_4 (13.20 g $hill^{-1}$), V_2T_4 (13.37 g $hill^{-1}$), V_1T_2 (13.80 g $hill^{-1}$) and V_2T_1 (15.07 g $hill^{-1}$).

Table 9: Effect of Seedling Hardening Treatment on Dry Matter Production at Different Growth Duration of Transplanted Rice

Treatments	**Total Dry Weight (g $hill^{-1}$) at**			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
T_1	3.32d	9.67c	12.27b	15.31c
T_2	3.81bc	11.56b	13.59b	17.01b
T_3	4.70a	14.45a	16.18a	20.09a
T_4	3.56cd	10.50bc	12.63b	15.16c
T_5	4.10b	13.32a	15.12a	18.07b
LSD $_{(0.05)}$	0.38	1.18	1.38	1.69
CV (%)	10.16	10.31	10.26	10.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

Table 10: Interaction Effect of Treatment on Dry Matter Production on the Performance of Transplanted Rice at Different DAT

Variety x Treatment	Total Dry Weight (g hill^{-1}) at Different DAT			
	30 DAT	45 DAT	60 DAT	75 DAT
Pajam (V_1)				
T_1	3.97b-e	10.63de	12.73d-f	12.87e
T_2	4.33bc	13.59a-c	14.23b-e	13.80e
T_3	5.20a	15.42a	18.43a	18.70a-c
T_4	4.20bc	12.60b-d	13.73b-f	13.20e
T_5	4.57ab	14.47ab	15.47bc	16.87cd
BRRI dhan53 (V_2)				
T_1	2.63g	9.11e	11.77f	15.07de
T_2	2.97fg	10.33e	13.17c-f	17.93b-d
T_3	3.93c-e	14.20a-c	15.07b-d	20.47ab
T_4	2.97fg	9.27e	11.43f	13.37e
T_5	3.17fg	12.40cd	15.63b	17.03cd
BRRI hybriddhan4 (V_3)				
T_1	3.37ef	9.27e	12.30ef	18.00bcd
T_2	4.13b-d	10.76de	13.37b-f	19.30a-c
T_3	5.00a	13.73a-c	15.03b-d	21.10a
T_4	3.50d-f	9.63e	12.73d-f	18.90a-c
T_5	4.57ab	13.10bc	14.27b-e	20.30ab
$LSD_{(0.05)}$	0.66	2.05	2.39	2.94
CV (%)	10.16	10.31	10.26	10.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.
T_1 = Direct transplanting, T_2 = Storage in shed, T_3 = Storage in open field, T_4 = Storage in water, T_5 = Storage in cool air.

Number of Effective Tillers Hill^{-1}

The effective tiller varied significantly due to variety. It was observed that BRRI hybriddhan4 produced significantly higher effective tiller (12.07). The second highest effective tiller (7.12) was measured from BRRI dhan53 and the lowest effective tiller (6.48) was obtained from Pajam.
Storage in open field condition gave the highest effective tiller (9.8111) (Table 11). The second highest effective tiller (9.09) was obtained from the effect of storage in cool air condition. Direct transplanting of seedling in the field gave the lowest effective tiller (7.32).
Effective tiller was significantly affected by the interaction of variety and different conditions (Fig 7). The highest effective tiller (13.40) was obtained from the combination BRRI hybriddhan4 with Storage in open field. Second highest effective tiller (12.47) was obtained from the combination of BRRI hybriddhan4 with storage in cool air condition which was statistically similar with BRRI hybriddhan4 with storage in shade condition. The lowest (4.63) was found from the combination Pajam with direct transplanting which was statistically similar with storage in shade condition of Pajam and storage in water and direct transplanting treatment of BRRI dhan53 seedling.

Non-effective Tillers Hill^{-1}

The non-effective tiller varied significantly due to variety. It was observed that Pajam produced the highest non-effective tiller (2.54). The lowest non-effective tiller (0.98) was measured from BRRI hybriddhan4.
Different treatments had significant effect on non-effective tiller (Table 12). Storage in open field condition gave the highest non-effective tiller (2.04) which is statistically similar with Storage in cool air and storage in shed. The lowest non-effective tiller (1.36) was measured from direct transplanting.
Non-effective tiller was significantly affected by the interaction of variety and treatments (Fig 9). The highest non-effective tiller (2.87) was obtained from the combination Pajam with storage in open field condition which

was statistically similar with storage in cool air and storage in shade condition of same variety Pajam. Second highest non effective tiller (2.37) was obtained from the combination of BRRI dhan53 with storage in open field treatment of the seedlings. The lowest (0.90) was found from the combination BRRI hybriddhan4 with storage in open field which was statistically similar with seedlings of direct transplanting of both BRRI dhan53 and BRRI hybriddhan4.

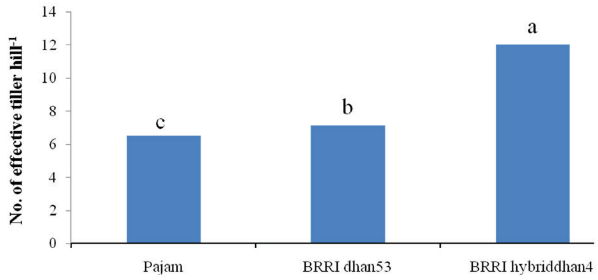

Figure 6: Effect of Variety on Effective Tillers hill^{-1} of Transplanted Rice. Bars with Similar Letter Do'nt Differ Significantly at $P \leq 0.05$ Applying LSD Test.

Table 11: Effect of Hardening Treatment on Effective Tillers hill^{-1} of Transplanted Rice

Hardening Treatments	Number of Effective Tiller hill^{-1}
Direct transplanting (T_1)	7.32d
Storage in shed (T_2)	8.62b
Storage in open field (T_3)	9.81a
Storage in water (T_4)	7.84c
Storage in cool air (T_5)	9.09b
LSD $_{(0.05)}$	0.51
CV (%)	6.16

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

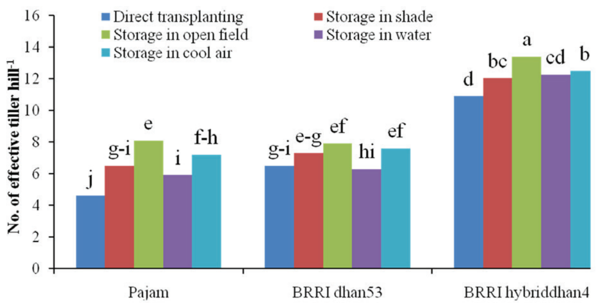

Figure 7: Interaction Effect of Variety and Hardening Treatment on Number of Effective Tillers hill^{-1} of Transplanted Rice. Bars with Similar Letter Don't Differ Significantly at $P \leq 0.05$ Applying LSD Test.

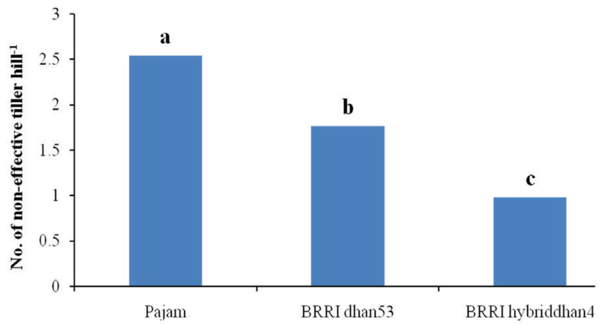

Figure 8: Effect of Variety on Non-effective Tiller hill^{-1} of Transplanted Rice. Bars with Similar Letter Don't Differ Significantly at $P \leq 0.05$ Applying LSD Test.

Table 12: Effect of Hardening Treatment on Non-effective Tillers hill^{-1} of Transplanted Rice

Hardening Treatments	Number of Non-effective Tiller hill^{-1}
Direct transplanting (T_1)	1.36c
Storage in shed (T_2)	1.90a
Storage in open field (T_3)	2.04a
Storage in water (T_4)	1.58b
Storage in cool air (T_5)	1.93a
LSD $_{(0.05)}$	0.15
CV (%)	8.72

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) different significantly at 0.05 level of probability following LSD test.

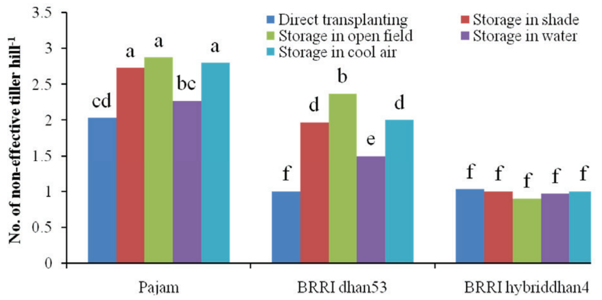

Figure 9: Interaction Effects of Variety and Hardening Treatment on Number of Non-effective Tillers hill^{-1} of Transplanted Rice. Bars with Similar Letter Don't Differ Significantly at $P \leq 0.05$ Applying LSD Test.

DISCUSSION

Plant heights of the rice varieties significantly differ due to their genotypic characters. However, the hardening could not affect the plant heights much because the standing crops were not given any additional treatments. Number of tillers in different rice varieties was also affected by hardening treatments. Different hardening treatment during seedling stage could able the plants to initiate metabolic defense and hence they could produce higher capacity to produce photosynthate [11, 12]. Cold hardening treatments have some beneficial effects on metabolic and physiological processes of plant which improves the cold tolerance in different crops [8-12]. The underlying mechanism(s) how seedling hardening can enhance the growth and productivity of transplanted crops may be their cross-adaptation process. Short-term adverse condition of seedling just before transplanting may induce the upregulation of defense mechanisms in plants which would be active during the subsequent episodes after transplantation to provide healthy plants with better productivity of rice seedlings. In this study, DM production was higher in hybrid varieties. Main *et al*. [21] also observed that hybrid rice produced more dry matter in plant than inbred varieties. Due to better photosynthetic capacity and protection from oxidative stress the seedlings which were hardened produced higher DM under field condition. These results also supported by other researchers [4, 11].

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CONFLICTS OF INTEREST

Authors declare that there is no conflict of interest for the present study.

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