EFFECT OF PRE-PLANTING HARDENING OF SEEDLING ON THE PERFORMANCE OF INBREED AND HYBRID AMAN RICE

BY

SADIA MASRUFA

REGISTRATION No. 08-03034

A Thesis Submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE
IN
AGRONOMY
SEMESTER: JULY-DECEMBER, 2014

APPROVED BY

....	....
Dr. Mirza Hasanuzzaman	**Prof. Dr. Md. Hazrat Ali**
Supervisor	**Co-supervisor**

....

Prof. Dr. H. M. M. Tariq Hossain
Chairman
Examination Committee

Department of Agronomy

her-e Bangla Agricultural University

Sher-e-Bangla Nagar

Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, "***EFFECT OF PRE-PLANTING HARDENING OF SEEDLING ON THE PERFORMANCE OF INBREED AND HYBRID AMAN RICE***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by SADIA MASRUFA, Registration no. 08-03034 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date: 23.11.2015

Place: Dhaka, Bangladesh

....

Dr. Mirza Hasanuzzaman

Associate Professor

Department of Agronomy

Sher-e-Bangla Agricultural University

Dhaka-1207

DECLARATION

I do hereby declare that thesis entitled ***"Effect of pre-planting hardening of seedling on the performance of inbreed and hybrid aman rice"*** has been written and composed by myself with

My own investigated research data.

I further declare that this thesis has not been submitted anywhere in any form for any academic degree.

December 2014

Sadia Masrufa

ACKNOWLEDGEMENT

There are a number of individuals for which I would like to recognize for their contribution to my development and success. First and foremost with a deep sense of gratitude and indebtedness, I thank my research supervisor Dr. Mirza Hasanuzzaman, Associate Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his invaluable guidance, constructive criticism, encouragement and keen interest. My experience with his has inculcated in me qualities that will always remain ingrained in my heart, mind and soul. His scientific, methodical, focused and positive approach combined with exceptional zeal and dynamism is some of the qualities which I admire most and I often yearn for them. His constructive criticism and frequent discussion inspired me to go ahead in difficult times and cope up with every little problem during my thesis.

I would also like to express my deepest sense and gratitude to my co-supervisors Prof. Dr. Md. Hazrat Ali, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his valuable advice and encouragement during the study and preparing of the dissertation.

I avail this opportunity to express my sincere thanks and profound appreciation to the departmental Chairman Dr. H. M. M. Tariq Hossain along with all the teachers and stuff members of the Department of Agronomy, SAU, Dhaka-1207, for their co-operation and support during the study.

I would also like to acknowledge the moral support, encouragement and cooperation from my lab mates including Shamol Chandra Devnath, Jannatul Ferdus, Soheli Sarker and Md Abu Naim. Special thanks to Md. Hasanuzzaman, Assistant Professor, SAU, Md. Anisur Rahman, Assistant Professor, SAU.

I would like to thank my parents and sister for their unconditional love and support they have lent for many years. None of my success I am able to celebrate would be possible without the values they have instilled in me. Next, I would like to extend gratitude and thanks to all of my family members, relatives and friends for their blessings, continuous support and inspiration in all phases of my academic endeavors.

I specially acknowledge the Ministry of Science and Technology, Government of the People's Republic of Bangladesh for providing National Science and Technology Fellowship with financial support.

Last but not least, I thank Almighty ALLAH who granted me the power of vision and wisdom to unknot the mysteries of the universe in a more systematic manner what people call it 'Science' and enables me to complete the research work and the thesis leading to Master of Science.

December 2014 **The Author**

EFFECT OF PRE-PLANTING HARDENING OF SEEDLING ON THE PERFORMANCE OF INBREED AND HYBRID AMAN RICE

ABSTRACT

The experiment was conducted with a view to investigate the pre-planting hardening of seedling on the performance of inbreed and hybrid aman rice at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during aman season (July to December, 2013). The experiment was carried out with three varieties *i.e.* BRRI dhan53, BRRI hybriddhan4, and Pajam and five seedling hardening treatment methods viz. direct transplanting (T_1), storage in shade condition for three days (T_2), storage in open field condition for three days (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 revealed that in open field condition, Pajam variety was significantly increased in plant height, number of effective tillers, leaf area index (LAI) and total dry matter (TDM) at 30DAT and 45DAT, respectively but later on BRRI hybriddhan4 showed the highest result. Yield attributing parameters, such as panicle length, grain number panicle^{-1}, 1000 grain weight and yield were improved due to the treatments. The highest grain yield (7.26 t ha^{-1}) was in BRRI hybriddhan4 under open field storage condition. However, the lowest grain yield (2.31 t ha^{-1}) was found in BRRI dhan53 with direct transplanting combination.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

Chapter 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple 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. Rice 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 (IRRI, 2013). It is the grain with the second-highest worldwide production, after corn. Bangladesh is the fourth highest rice (*Oryza sativa* L.) producing country in the world (FAO, 2013).

Rice is grown on about 11.56 million hectares which has remained almost stable over the past three decades. About 76.71% of the total cropped area is planted to rice in the year 2012-13. Total rice production in Bangladesh was about 10.59 million tons in the year 1971 when the country's population was only about 70.88 millions. However, the country is now producing about 34.00 million tons to feed her 149.69 million people (Mondal and Choudhury, 2014). 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 (Julfiquar *et al.*, 2009).

Rice is extensively grown in three seasons of Bangladesh viz., aus, aman and boro, which covers 80% of the total cultivable area (AIS, 2011). Aman rice holds the major share of acreage. At present aman is the second largest crop in the country in respect of the volume of production and is highest as a single crop. Total area under aman crop of 2014-15 has been estimated at around 1.4

crore acres in this fiscal year and no change in area under aman took place in 2014 as regards to previous year and the total aman production of 2014-15 has been estimated at 14 million metric ton as compared to 13 million metric ton which is 1.3% higher than that of last year (BBS, 2014). Though the yield of rice in Bangladesh is generally has increased, it is still much lower than the genetic potential yield. However, the genetic potentiality may not be achieved due to various environmental and socio economic conditions. This 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 (Better Vegetable Gardening, 2012). 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 (Boese and Huner, 1990; Castonguay *et al*, 1995; Rajshekar and Lafta, 1996; Uemura and Steponkus, 1997; Gogoi and Baruah, 1999). 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 try to elucidate it; most are based on roles of H_2O_2, antioxidants (glutathione and ascorbic acid and heat shock proteins (HSPs) Hsu and Kao 2007; Chao *et al.* 2009, 2010; Chao and Kao 2010; Ferreira-Silva *et al.* 2011; Ao *et al.*, 2012). Later on, Chao and Kao (2010) 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 (Chou *et al.*, 2012). Ferreira-Silva *et al.* (2011) 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 (Farooq *et al.* 2005). 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 (*Oryza sativa* L.) seedlings.

The population of Bangladesh is increasing day by day and that is why horizontal expansion of aman rice area is not possible due to high population pressure on land. Therefore, 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. (Alauddin, 2004).

Thus a detailed study with an inbreed and a hybrid variety with some pre planting hardening of seedling treatment were undertaken with the following objectives:

i. To investigate the effect of seedling hardening on the performance of aman rice

ii. To find out a suitable hardening methods for rice seedlings

iii. To compare the relative performance of local, HYV and hybrid rice under different hardening treatment.

Chapter 2

REVIEW OF LITERATURE

In Bangladesh, Transplanted aman rice grown in the area where the depth of water does not usually exceed 0.5m. Very often the transplanting schedule of transplanting aman rice cannot be maintained in this country particularly in the low lying areas due to tidal inundation of flash flood caused by incessant rainfall. On the contrary, the scarcity of rice seedling of transplant aman after recession of flood water was also a common phenomenon for the last few years. Proper attention had not been given on the storage condition before transplanting due to unfavorable conditions in over country. Experimental evidences on these aspects are so rare both home and abroad. However, the available literature related to the storage condition before transplanting of uprooted rice seedlings have been presented below.

2.1 Effect of variety

Debnath *et al.* (2012) observed that variety had significant effect on all the agronomic parameters except number of effective tillers, ineffective tillers, total tillers, grain straw ratio and biological yield. BRRI hybrid dhan2 produced the highest dry grain yield (5.92 t ha^{-1}) and the lowest straw yield (4.97 t ha^{-1}), whereas, BRRI dhan29 produced the lowest grain yield (4.16 t ha^{-1}) and the highest straw yield (6.70 t ha^{-1}).

Al-Mamun *et al.* (2011) carried out an experiment at the Agronomy Farm of Bangladesh Rice Research Institute, Gazipur, During December 2008 to June 2009 in winter season on Surjamoni and BRRI dhan29 and observed that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10WP @ 150g ha^{-1}, which was 49% higher than control. BRRI dhan29 produced also the highest grain yield when treated with same treatment, which was 37% higher than control.

Bhuiyan *et al.* (2011) conducted a field experiment to evaluate the performance of different weed management options regarding effective weed control, yield and yield contributing characters of three popular BRRI aman varieties having different growth duration (BRRI dhan39, BRRI dhan49 and BR11) in 2008 and 2009 at Bangladesh Rice Research Institute, regional station, Rajshahi and found that among the varieties, BR11 produced significantly higher yield (5.02 t ha^{-1}) and lowest yield was recorded in BRRI dhan39 (3.58 t ha^{-1}).

Reza *et al.* (2010) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, during the period from January to April 2008 and found that Pajam produced the higher grain yield (4.0 t ha^{-1}) than BRRI dhan28 (2.79 t ha^{-1}).

Obaidullah (2007) stated that variety significantly influenced panicle length, number of total grains panicle', filled grains panicle1, 1000 grains weight, grain yield and straw yield but not for effective tillers hill' and harvest index. The varietal effects on yield and other yield attributes where hybrid variety gave numerically maximum tillers $hill^{-1}$ (10.08), and significantly highest panicle length (27.36 cm), grains $panicle^{-1}$ (196.75), filled grains $panicle^{-1}$ (156.84), 1000 grain weight (27.40 g) which eventually elevated the grain yield (5.58 t ha^{-1}). These parameters were 9.8, 25.17 cm, 112.83, 86.77, 20.09 g and 3.88 t ha^{-1}, respectively as lowest measurements from inbred varieties.

Main *et al.* (2007) reported that there was no significant variation of effective tillers $hill^{-1}$, total grains $panicle^{-1}$, filled grains panicle, straw yield and harvest index observed between the two varieties but hybrid variety showed higher panicle length, grain weight and grain yield compared to inbred variety. The variety Sonarbangla-1 gave the longer panicle (26.40 cm) compared to that of

BR11 (25.66 cm). The higher weight of 1000 grains (28.32 g) was obtained from the hybrid variety and the lower (27.08 g) was obtained from the inbred variety. The higher grain yield (4.70 t ha^{-1}) was obtained from the hybrid variety Sonar bangla-1 and from inbred variety BR11 (4.43 t ha^{-1}). Irrespective of variety clonal tillers showed the highest range of harvest index (48.52 to 49.55%) that was statistically similar with nursery seedlings of inbred variety. Ashrafuzzaman (2006) observed that variety significantly influenced total spikelet's $panicle^{-1}$, grains $panicle^{-1}$, 1000 grain weight, grain yield and harvest index. The higher number of spikelet's $panicle^{-1}$ (178.04) was obtained from the inbred variety BRRI dhan32 and the lower number of grains $panicle^{-1}$ (155.49) was obtained from the hybrid variety sonarbangla-1. The inbred variety showed 14.50% higher number of total spikelet's $panicle^{-1}$ compared to hybrid variety. The higher number of grains $panicle^{-1}$ (147.59) was counted in the inbred variety and the lower (111.98) number were counted in the hybrid variety. The higher weight of 1000 grains (27.12 g) was obtained from the hybrid variety and the lower (21.89 g) from the inbred variety. The higher grain yield (5.46 t ha^{-1}) was obtained from the hybrid variety compared to that of inbred variety (4.45 t ha^{-1}). The grain yield was 20.26% higher in the hybrid variety than the inbred variety. The higher harvest index (47.53%) was found from the hybrid variety and the lowest harvest index (43.20%) was found in inbred variety. The harvest index was 10.07% higher in the hybrid variety compared to the inbred variety. Similar results were also reported by Cui *et al.* (2000).

Akbar (2004) stated that variety, seedling age and their interaction exerted significant influence on almost all the studied crop characters of rice. Among the varieties, BRRI dhan41 performed the best in respect of number of bearing tillers $hill^{-1}$, panicle length, total spikelet's $panicle^{-1}$, and number of grains $panicle^{-1}$. BRRI dhan41 also produced the maximum grain and straw yields, Sonarbangla-1 ranked first in respect of total tillers $hill^{-1}$ and 1000 grain weight but produced the highest number of non-bearing tillers hill and sterile spikelet's panicle^{-1}. Grain, straw and biological yields were found highest in the combination of BRRI dhan41 x 15 day-old seedlings. Therefore, BRRI dhan41 may be cultivated using 15 day-old seedlings in aman season following the SRI technique to better grain and straw yields.

In a trial, varietal differences in harvest index and yield were examined using 60 Japanese varieties bred in Asian countries. It was reported that harvest index varied from 36.8% to 53.4%. Mean values of harvest index were 43.5% in the Japanese group and 48.8% in high yielding group. Yield ranged from 22.6 g plant^{-1}. The mean value of yield in Japanese group was 22.8 g plant^{-1}, and that in high yielding group was 34.1 g plant^{-1}. They also reported that a positive correlation was found between harvest index and yield in the yielding group (Cui *et al.* 2000).

Om *et al.* (1999) conducted a field experiment with four varieties (3 hybrids: ORI 161, PMS 2A, PMS 10A and one inbred variety HKR 126) during rainy season and observed that hybrid ORI 161 exhibited superiority to other varieties in grain yield and straw yield.

Tac *et al.* (1998) conducted an experiment with two varieties, Akitakomachi and Hitombore in tohoku region of Japan. It was found that Hitombore yielded the higher (710 g m^{-2}) and Akitakomachi the lowest (660 g m^{-2}).

Ahmed *et al.* (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved variety, Nizersail. The fertilizer dose was 60-60-40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the varieties and found that percent filled grain was the highest in Nizersail followed by BR25 and the lowest in BR11 and BR23.

WenXiong *et al.* (1996) reported that Shnyou 63 (Zhenshan 97A x Minhui 63) and Teyou 63 (Longtepu A x Minhui 63) showed significant grain yield increase over Minhui 63 of 35.2 and 48%, respectively, in China in 1993. The higher number of productive tillers plant^{-1} had the largest direct effect on grain yield, resulting in increased sink capability. The higher tiller number and number of grains panicle^{-1} were attributable to higher leaf areas, higher net photosynthesis in individual leaves (particularly in the later stages) and favorable partitioning of photosynthesis to plant organs. Compared with Minhui 63, hybrids showed slight heterosis in relative growth rate but significant heterosis in crop growth rate, especially at later growth stages, with increases of 160.52 and 97.62% in shanyou 63 and Teyou 63, respectively.

BINA (1993) evaluated the performance of four varieties- IRATOM 24, BR 14, Binadhan-13 and Binadhan-9. It was found that the varieties differed significantly in respect of plant height, number of unproductive tillers hill^{-1}, panicle length and sterile spikelets panicle^{-1}.

Leenakumari *et al.* (1993) found higher grain yield from the hybrid varieties over the modern varieties. They evaluated eleven hybrids of varying duration against controls Jaya, Rasi, IR20 and Margala, and concluded that hybrid OR 1002 gave the highest yield (7.9 t ha^{-1}) followed by IR 1000 (6.2 t ha^{-1}).

BRRI (1991) reported that the number of effective tillers produced by some transplant aman rice ranged from 7 to 14 tillers hill^{-1} and it significantly differed from variety.

In a trail with six modern varieties in haor area during Boro season it was recorded that rice grain yield differed significantly where 4.59, 5.3, 5.73, 4.86, 3.75 and 4.64 t ha^{-1} of grain yield were recorded with BR3, BR11, BR14, IR8, Pajam and BR16, respectively (Hossain *et al.*, 1991).

BRRI (1985) concluded that BR4 and BR10 were higher yielders than Rajasail and Kajalsail.

Miller (1978) from a study of 14 rice cultivars observed that grain yields ranged from 5.6 to 7.7 t ha^{-1}. He also reported that grain yield was significantly influenced by rice cultivars.

Kumber and Sonar (1978) also reported variable effects of rice varieties on grain yield. Om *et al.* (1999) observed that hybrid variety exhibited superiority to other inbred varieties in grain and straw yield.

Chang and Vergara (1972) stated that the tillering pattern of rice varied with the varieties. In general tall cultivars showed a tendency to have small number of tillers and shorts on showed a large number. Tiller number and panicle number were positively correlated. Tall tropical and subtropical cultivars tend to have a low ratio of panicle to tillers. *Japonica* cultivars that produced few tillers under tropical conditions were vigorous and produced more tillers when grown under temperate conditions. *Indica* cultivars, which were vigorous under tropical conditions, showed few tillers under temperate conditions.

2.2 Effect of seedling storage condition

Higher seedling survival under flooded conditions was observed in pre-soaked or primed seeds than in non-primed seeds. Priming increased the percentage of seeds with emerging shoots and roots under flooded conditions, and also the rate of shoot and root growth. This was also observed in other crops but under aerated conditions, as in lucerne (Zhang *et al.* 2007), muskmelon (Nascimento 2003) and sorghum (Tiryaki and Buyukcingil 2009). Similar effects were also observed when seeds were pre-soaked with water for 24 hr before sowing.Wheat plants exposed to water stress showed poor growth with low plant height, yield and yield

Components such as number of tillers per plant, spike length, number of grains per spike, biological yield, grain yield and harvest index as compared to plants grown under well watered condition. The reduction in plant height might be due to reduction in cells expansion and more senescence of crop leaves under drought stress (Bhatt and Srinivasa Rao, 2005).

Farooq *et al.* (2005) reported that thermal hardening treatments did not affect germination percentage and radical length. This observation of Farooq *et al.* (2005) might be due to good quality of seeds of both species of rice (indicant japonica) used in that study similar to cabbage variety GA in our study. They recorded higher germination energy in treated seeds similar to the results of cabbage variety GB.

This promoting effect of seed hardening treatment can be attributed to enlargement of the embryo before imbibitions (Austin *et al.*, 1969) Moreover, there was no significant difference in GE, GI and VI values of cabbage variety GB seeds exposed first to dry heat treatment compared with seeds subjected to chilling first as reported by Farooq *et al.* (2005).

Kaykobad *et al.* (2003) conducted an experiment to evaluate the effect of storage conditions and storage duration of uprooted seedlings with five storage conditions such as in mud, in water, in shade ,in sun and in shade with frequent watering and four storage durations (0, 24, 48 and 72 hours of storage seedlings). Best performance was exhibited by seedling stored in mud followed by those stored in water, in shade with time to time watering and in sun and the difference was significant. Some decrease in the value of subsequent crop characters occurred with an increase in the period of storage from 0-72 hour's .However, the differences between treatments were not significant.

Sarkar *et al.* (2003) conducted an experiment at Cuttack, Orissa, India where seeds of 6 rice cultivars (Tulasi, FR 13A, T 1471, Sabita, Kolasali and CH 19) were sown in moistened soil and maintained after 5 days under 5 cm of water were compared with 30-day-old seedlings transplanted in the normal way. Compared with transplanting, the crops from anaerobic direct sowing had greater plant height and above-ground dry matter, less chlorophyll and specific leaf weight, and more panicles per unit area and sterile spikelets. Panicle weight and harvest index had significantly positive associations with grain yield.

A field experiment was conducted by Kumar *et al.* (2002) during kharif 1998 and 1999 in New Delhi, India, to determine the proper age of seedling and appropriate plant density of a scented (Pusa RH-10) and non-scented (Pusa RH-6) hybrid rice. The treatments comprised 3 ages of seedlings (20, 25 and 30 days old) and 3 plant densities (25, 33 and 50 plants m^{-2}). The treatments comprised 3 ages of seedlings (20, 33 and 50 plants m^{-2}). Transplanting of 20 days old seedling exhibited higher growth and yield parameters and registered 11.6% higher grain yield over 30 days old seedlings. Plant density of 25 plants m^{-2} appeared more appropriate and yielded 7.6 and 17.5% higher grain yield over 33 and 50 plants m^{-2} respectively.

Haque (1997) observed that the uprooted seedlings of BR11 rice can be stored in water even up to 8 days in case of emergency and in the sun or shade for 0 to 2 days without any appreciable loss in grain yield.

BRRI (1996) conducted a field trial of preserving uprooted seedlings of BR23 and Sadamata rice varieties before transplanting in gunny, floating in water and on mud for 0, 5 and 10 days. The institute observed that seedlings of both the varieties preserved for 5 days give significantly higher grain yield than that those stored for 10 days in each of the storage conditions. The grain yield obtained from BR23 rice seedlings stored for 5 days under various conditions was identical to that of fresh seedlings which were not stored before transplanting. But the yield from the seedlings of the same storage condition for 10 days was significantly lower than that of fresh seedlings. The variety Sadamata also showed similar performance as did the variety BR23.

Water stress during seedlings stage to maturity of crop, significantly decreased all grain yield traits, particularly the number of productive tillers per unit area about 60%, and number of grains per spike by 48%(Giuanta *et al.*, 1993).

BRRI (1991a) reported that during the storage the dry matter content of 40 days old rice seedling was much higher than those of 20 days old ones at all the storage periods from 0 to 28 days under both water and mud storage conditions .The dry matter content of mud stored seedling was much higher than that of water stored ones at all storage periods, irrespective of seedlings age. A decreasing trend in the dry matter content of seedling was noticed with the increase of storage duration from 0 to 28 days.

BRRI (1991b) studied the effect of storage periods and storage conditions of uprooted BR11 rice seedlings and found about 85 percent seedlings survived and produced 3t/ha grain yields when those were stored for 4 weeks in mud. On the other hand, the survival percent of seedling stored for more than 4 weeks in water was very low. Survival percent was found to be better in older seedlings stored in water than that of younger ones. BRRI (1991c) revealed that a significant decrease in grain yield was observed due to storage of uprooted rice seedlings in mud than those transplanted immediately after uprooting irrespective of seedling age, although the grain yield was not less than about 3 t ha^{-1}. But in case of seedlings stored in water, the grain yield was severely affected in negative direction. However , more than 3t/ha of grain yield was obtained from 40 days old seedlings stored in water for 7 days, but the 20 day old seedlings stored for the same period in water produced much lower grain yield of only 1.4 t/ha.

Gomosta *et al.* (1990) evaluated the performance of uprooted rice seedlings which were stored in water as well as in mud for a number of days. They observed that 20 and 40 day old seedlings of BR11 rice, transplanted after 1 to 4 weeks of storage in mud, showed 85% survivability irrespective of age of seedlings. The survivability percentage decreased with the increase in storage duration in case of water storage. In some cases the grain yield became even nil when the seedlings were stored in water for 3 to 4 weeks. On the other hand, it varied from 2.8 to 3.5 ha^{-1} in case of mud storage of seedlings. They concluded that to obtain reasonable grain yield, uprooted seedlings of transplant aman rice should be stored in mud up to 4 weeks irrespective of seedling age ranging from 20 to 40 days.

Plant establishment in most crops is limited by environmental constraints, such as extremes of temperatures, drought and salinity, resulting in poor crop stands. Poor emergence rate under these conditions is the cause of uneven plant stands (Cantliffe *et al.*, 1987). BRRI (1985) studied the mortality of uprooted seedlings of BR4 imposing different storage conditions, either keeping erect in mud or packed in gunny bags for 3,6,9 and 12 days. Higher mortality percentage of uprooted seedlings was found when stored in gunny bags for more than 6 days and 100 percent mortality was observed when seedlings were stored for 12 days. The grain yield also showed the similar trend. Seedlings stored for more than 6 days in gunny bags also gave significantly lower grain yield, while no such reduction in yield was found in case of seedlings stored in mud up to 12 days.

Chapter 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from July 2013 to December 2013. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Geographical Location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above sea level .

3.2 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from

October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the Sher-e-Bangla Agricultural University Weather Station, Dhaka.

3.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. 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.

3.5 Experimental Plant materials and features

Rice cv. BRRI dhan53, BRRI hybriddhan4, and Pajam were used as plant materials for the present study. These varieties are recommended for aman season.

Pajam: It is a widely cultivated rice variety grown in aman season. It has moderate yield potential (2.5 t ha^{-1}). It is a tall variety having plant height 90-100 cm. Grain is medium sized. Life duration is 110 days approximately.

BRRI dhan53: BRRI dhan53 variety is grown in aman season. It is modern transplanted salt tolerate aman rice variety released by BRRI in 2010.The grains are of medium sized and slender. The cultivars mature at 125 days of planting. It attains a plant height of 105 cm. The cultivars give an average yield of nearly 4.5 ton ha^{-1}.

BRRI hybriddhan4: BRRI hybriddhan4 variety is grown in aman season. It is modern transplanted aman rice variety released by BRRI in 2010.The grains are of medium sized, slender, transparent and white in color. The cultivars mature at 118 days of planting. It attains a plant height of 112 cm. The cultivars give an average yield of 6.5 t ha^{-1}.

3.6 Experimental Treatments

Factor-A: Variety

- Pajam (V_1)
- BRRI dhan53 (V_2)
- BRRI hybrid dhan4 (V_3)

Factor-B: Hardening pre-treatment

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

The description of the hardening pre-treatments is given below:

Cold: Uprooted seedlings were tied in bundles and kept in cold temperature (4°) in refrigerator for 24 hour.

Direct sunlight: Uprooted seedlings were tied in bundle and placed upright under ambient condition with direct sunlight for 48 hour.

Water: Uprooted seedlings were kept under water for 48 hour.

Shade: Uprooted seedlings were kept in shade for 48 hour.

are of medium sized, slender, transparent and white in color. The cultivars mature at 118 days of planting. It attains a plant height of 112 cm. The cultivars give an average yield of 6.5 t ha^{-1}.

3.6 Experimental Treatments

Factor-A: Variety

- Pajam (V_1)
- BRRI dhan53 (V_2)
- BRRI hybrid dhan4 (V_3)

Factor-B: Hardening pre-treatment

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

The description of the hardening pre-treatments is given below:

Cold: Uprooted seedlings were tied in bundles and kept in cold temperature (4°) in refrigerator for 24 hour.

Direct sunlight: Uprooted seedlings were tied in bundle and placed upright under ambient condition with direct sunlight for 48 hour.

Water: Uprooted seedlings were kept under water for 48 hour.

Shade: Uprooted seedlings were kept in shade for 48 hour.

3.7 Design and layout

The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of the individual plot was 3.0 m × 3.0 m and total numbers of plots were 45. There were 15 treatment combinations. Each block was divided into 15 unit plots and the treatments were assigned in the unit plots at random. Variety was placed along the main plot and treatments were placed along the sub plot. Lay out of the experiment was done on August 2, 2013 with inter plot spacing of 75cm and inter block spacing of 1.2 m.

3.8 Seed collection, sprouting and sowing

Seeds of BRRI dhan53, BRRI hybriddhan4 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur. Seeds of pajam were collected from local market. Initially seed soaking was done in water for 24 hours and after wards they were kept tightly in jute sack for 2 days. When about 90% of the seeds were sprouted, they were sown uniformly in well prepared wet nursery bed on July 13, 2013. Seed bed size was 10 m long and 1.5 m wide.

3.9 Land preparation

The experimental field was first opened on July 24, 2013 with the help of a tractor drawn disc plough, later on August 2, 2013 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor plough and subsequently leveled by laddering. All kinds of weeds and residues of previous crop were removed from the field. After the final land preparation the field layout was made on August 4, 2013 according to experimental plan. Individual plots were cleaned and finally leveled with the help of wooden plank so that no water pocket could remain in the puddle field.

3.10 Fertilizer application

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 triple super phosphate, murate of potash, 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.

3.11 Uprooting and transplanting of seedling

The seedbeds were made wet by the application of water both in the morning and evening on the previous day before uprooting for treatment on August 3 and 5 (cold), 2013. 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 days and in cold temperature for 1 day before they were transplanted. The twenty five days old seedlings were transplanted on the well puddle experimental plots on August 6, 2013 by using two seedlings hill^{-1}.

3.12 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.12.1 Gap filling

After one week of each transplantation, a minor gap filling was done as and where necessary using the seedling from the previous source as per treatment. No thinning was done for any treatment.

3.12.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for each treatment; first weeding was done at 20 days after transplanting followed by second weeding at 15 days after first weeding.

3.12.3 Irrigation and drainage

The experimental plots required two irrigations during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.12.4 Plant protection measures

There were negligible infestations of insect-pests during the crop growth period. Yet to keep the crop growth in normal, Basudin, Ripcord was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control stem borer and rice bug.

3.13 General observations of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller and rice hispa was observed during tillering stage that controlled properly. No bacterial and fungal disease was observed in the field.

3.14 Harvest and post-harvest operation The maturity of crop was determined when 85% to 90% of the grains become golden yellow in color. From the centre of each plot 1 m^2 was harvested to determine yield of individual treatment and converted into t ha^{-1}. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, ten hills were selected randomly outside the sample area of each plot and cut at the ground level for collecting data on yield contributing characters.

3.15 Collection of data

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. The followings data were recorded during the experiment.

Crop growth parameters

a. Plant height (cm) at 15 days interval up to harvest.

b. Tillers $hill^{-1}$ at 15 days interval up to harvest.

c. Dry matter weight of plant at 15 days interval

Yield Contributing Characters

a. Effective tillers $hill^{-1}$

b. Non effective tillers $hill^{-1}$

c. Length of panicle (cm)

d. Fertile spikelets (filled grains) $panicle^{-1}$

e. Sterile spikelets (unfilled grains) $panicle^{-1}$

f. Weight of 1000 grains (g)

g. Grain yield (t ha^{-1})

h. Straw yield (t ha^{-1})

i. Biological yield (t ha^{-1})

j. Harvest index (%)

3.16 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study is given below:

3.16.1 Plant height

Plant height was measured at 30, 45, 60 and 75 DAT and at harvest. The height of the randomly pre-selected 5 hills $plot^{-1}$ was determined by measuring the distance from the soil surface to the tip of the leaf height before heading, and to the tip of panicle after heading. The collected data were finally averaged.

3.16.2 Number of tillers $hill^{-1}$

Number of tillers $hiil^{-1}$ were counted at 30, 45, 60 and 75 DAT and at harvest from five randomly pre-selected hills and averaged as their number $hill^{-1}$.

3.16.3 Number of leaves $hill^{-1}$

Number of leaves $hiil^{-1}$ were counted at 30, 45, 60 and 75DAT and at harvest from five randomly pre-selected hills and finally averaged as their number $hill^{-1}$ basis.

3.16.4 Leaf area Index

Leaf area index were estimated by measuring the length and width of leaf and multiplying by a factor of 0.75.

3.16.5 Dry weight of plant

The 3 hills plot^{-1} was uprooted from second line and oven dried (sub-sample) until a constant level from which the weights of above ground dry matter were recorded.

3.16.6 Effective tillers hill^{-1}

The panicles which had at least one grain was considered as effective tillers. The number of effective tillers hill^{-1} was recorded and finally averaged for counting effective tillers number m^{-2}.

3.16.7 Non-effective tiller hill^{-1}

The tiller having no panicle was regarded as ineffective tillers. The number of ineffective tillers hill^{-1} was recorded and finally averaged for counting ineffective tillers number hill^{-1}.

3.16.8 Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

3.16.9 Filled grains panicle^{-1}

Grain was considered to be filled if any kernel was present there in. The number of total filled grains present on ten panicles were recorded and finally averaged.

3.16.10 Unfilled grains panicle^{-1}

Unfilled grains means the absence of any kernel inside in and such grains present on each of five panicles were counted and finally averaged.

3.16.11 Total grains panicle^{-1}

The number of filled grains panicle^{-1} plus the number of unfilled grains panicle^{-1} gave the total number of grains panicle^{-1}.

3.16.12 Weight of 1000-grains

One thousand cleaned dried grains were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained about 12% moisture and the mean weight were expressed in gram.

3.16.13 Grain yield

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1}.

3.16.14 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot. After separating of grains, the sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.16.15 Biological yield

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated with the following formula:

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

3.16.16 Harvest Index

It denotes the ratio of economic yield to biological yield and was calculated with following formula

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

3.17 Statistical analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factor split plot design with the help of computer package XLSTAT 2014 and mean separation will be done by LSD at 5% level of significance.

Chapter 4

RESULT AND DISCUSSION

4.1 Plant height

4.1.1 Effect of variety

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. While the lowest plant height was observed in the variety BRRI dhan53 and Pajam. At 30 DAT, Pajam scored the highest plant height (64.63 cm) and the lowest plant height (54.03 cm) was observed from BRRI dhan53 which is statistically similar with BRRI hybriddhan4. On 45 DAT. BRRI hybriddhan4 was recorded the highest plant height (80.23cm) which was statistically similar (78.83 cm) with Pajam and BRRI dhan53 was recorded the lowest plant height (60.80 cm). In case of 60 DAT, the highest plant height (91.30 cm) was recorded by BRRI hybrid dhan4 and Pajam whether the lowest plant height (74.20 cm) was recorded from BRRI dhan53. At 75 DAT and at harvest, the highest plant height was recorded from BRRI hybriddhan4 and the lowest plant height 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.

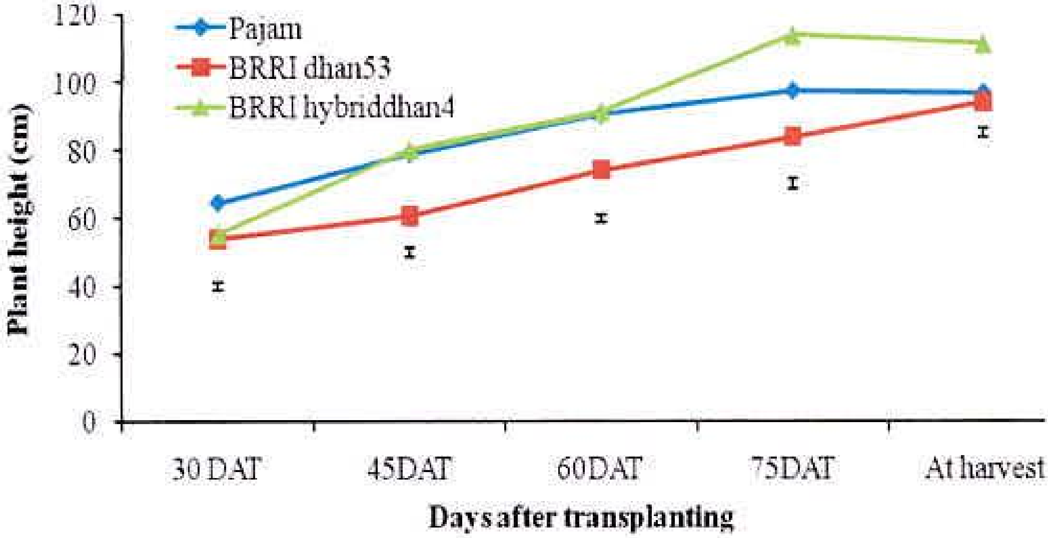


Figure 1. Effect of varieties on plant height of transplanted aman rice at different growth stages ($LSD_{0.05}$ Value 1.26, 1.35, 1.19. 1.45 and 1.32 at 30, 45, 60, 75 DAT and at harvest, respectively) Vertical bars indicate the LSD values

4.1.2 Effect of treatment on variety

Significant variation of plant height was found due to different seedling hardening treatment in all the studied durations (Table 1). The results revealed that at 30 DAT, the tallest plant (72.19cm) 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 (82.21cm) 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).

Table 1. Effect of seedling hardening treatment on plant height (cm) at different growth duration of transplanted aman rice

Treatments	Plant height (cm) at different DAT				
	30	45	60	75	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 latter(s) are statistically similar and those having dissimilar latter(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

4.1.3 Interaction effect of variety and seedling hardening treatment

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 (76.77cm) 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 (112.23cm) 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) of BRRI hybriddhan4 variety which was statistically similar with T_5 (121.93cm) of BRRI hybriddhan4 variety and the shortest plant (83.90 cm) was obtained from the direct transplanting seedlings of BRRI dhan53 variety which was statistically similar with the storage in water treatment (86.83 cm) of BRRI dhan53 variety. At harvest, the tallest plant (128.87) was obtained from observed from T_3 (128.87 cm) of BRRI hybriddhan4 variety which was statistically similar with T_5 (123.90cm) 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 2. Combined effects of variety and treatments on plant height (cm) of transplanted aman rice at different DAT

Variety	Treatment	Plant height (cm) at				
		30DAT	45DAT	60DAT	75DAT	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 (V_3)	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 latter(s) are statistically similar and those having dissimilar latter(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.

4.2 Number of tillers hill^{-1}

4.2.1 Effect of variety

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} (10.57cm) was recorded from Pajam .

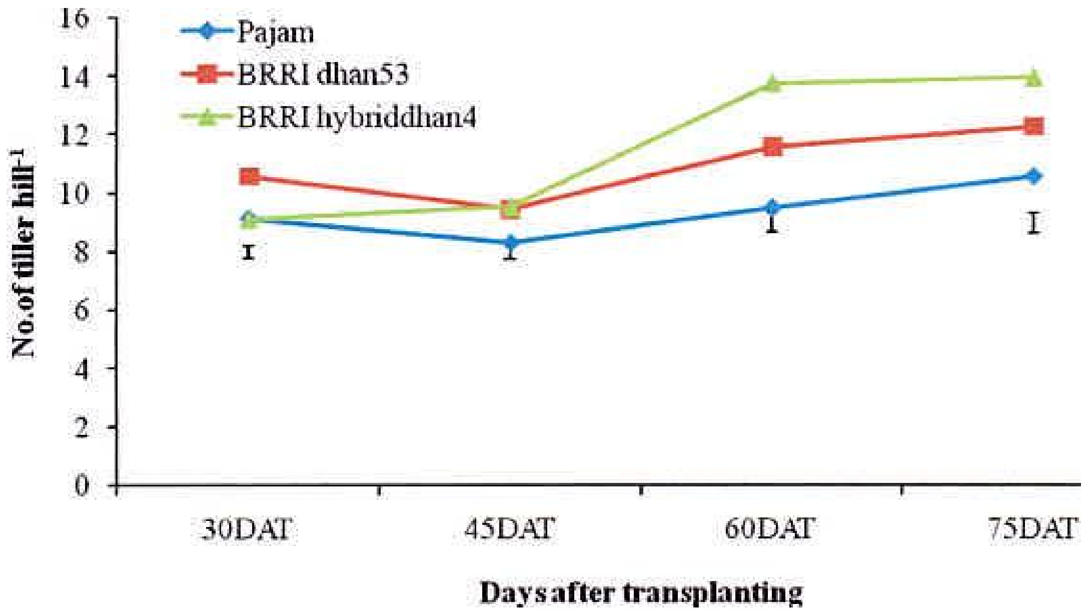


Figure 2. Effect of variety on tillers hill^{-1} of transplanted aman rice at different days after transplanting ($LSD_{0.05}$ value 0.22, 0.24, 0.33 and 0.34 at 30, 45, 60 and 75 DAT, respectively). Vertical bars indicate the LSD values

4.2.2 Effect of treatments

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).

Table 3. Effect of seedling hardening treatment on number of tillers hill^{-1} at different growth duration of transplanted aman rice

Treatments	Number of tillers hill^{-1} at different DAT			
	30	**45**	**60**	**75**
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 latter(s) are statistically similar and those having dissimilar latter(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

4.2.3 Interaction effect of variety and hardening treatments

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, 18.30and 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.

Table 4. Combined effect of variety and treatments on number of tillers hill^{-1} of transplanted aman rice at different DAT

Variety	Treatment	Number of tillers hill^{-1} at			
		30DAT	**45DAT**	**60DAT**	**75DAT**
	T_1	9.13g	8.300h	9.500j	10.57i
	T_2	9.07g	10.30fg	11.167i	13.43efg
Pajam (V_1)	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
	T_1	10.57e	9.43g	11.57hi	12.27gh
BRRI dhan53	T_2	13.20ab	10.53ef	13.07fg	12.67fgh
(V_2)	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
	T_1	9.10g	9.533fg	13.73ef	13.93def
	T_2	10.80de	11.37de	14.67de	16.00bc
BRRI hybriddhan4	T_3	11.63cd	99.13a	115.17a	127.27a
(V_3)	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 latter(s) are statistically similar and those having dissimilar latter(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.

4.3 Number of leaves $hill^{-1}$

4.3.1 Effect of variety

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.

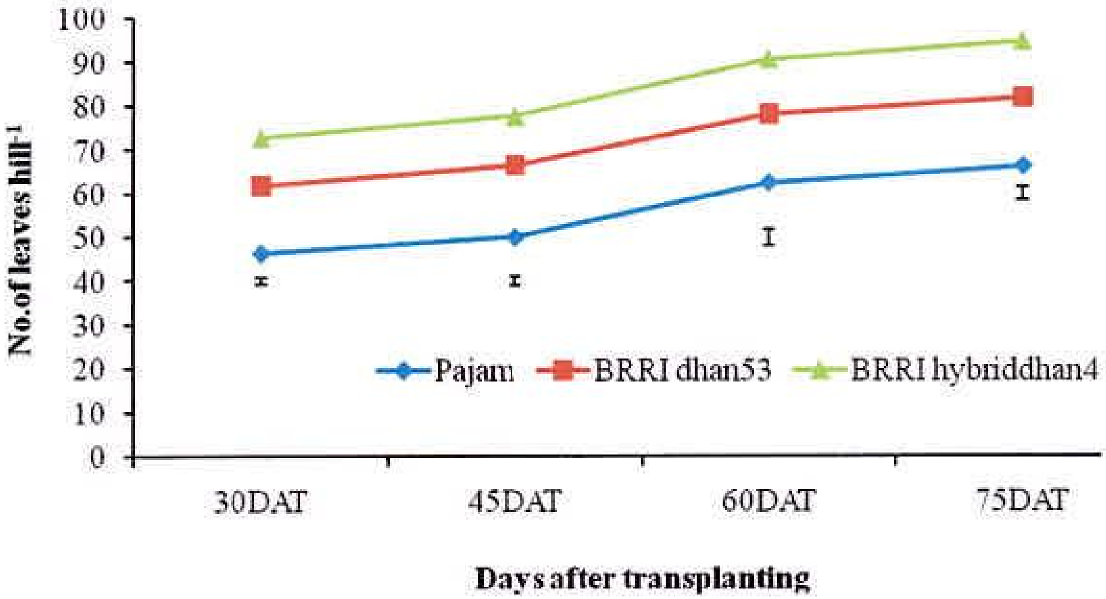


Figure 3. Effect of variety on number of leaves $hill^{-1}$ at different days after transplanting on aman rice ($LSD_{0.05}$ value 0.74, 1, 1.85 and 1.56 at 30, 45, 60 and 75 DAT, respectively) Vertical bars indicate the LSD values

4.3.2 Effect of treatments

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).

Table 5. Effect of seedling hardening treatment on number of leaves hill^{-1} at different growth duration of transplanted aman rice

	Number of leaves hill^{-1} at different DAT			
Treatments	**30**	**45**	**60**	**75**
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 latter(s) are statistically similar and those having dissimilar latter(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

4.3.3 Interaction effect of variety and treatments

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.

Table 6. Combined effects of variety and treatments on number of leaves hill^{-1} of transplanted aman rice at different DAT

Variety	Treatment	Number of leaves hill^{-1} at			
		30DAT	45DAT	60DAT	75DAT
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 latter(s) are statistically similar and those having dissimilar latter(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.

4.4 Leaf area index (LAI)

4.4.1 Effect of variety

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.

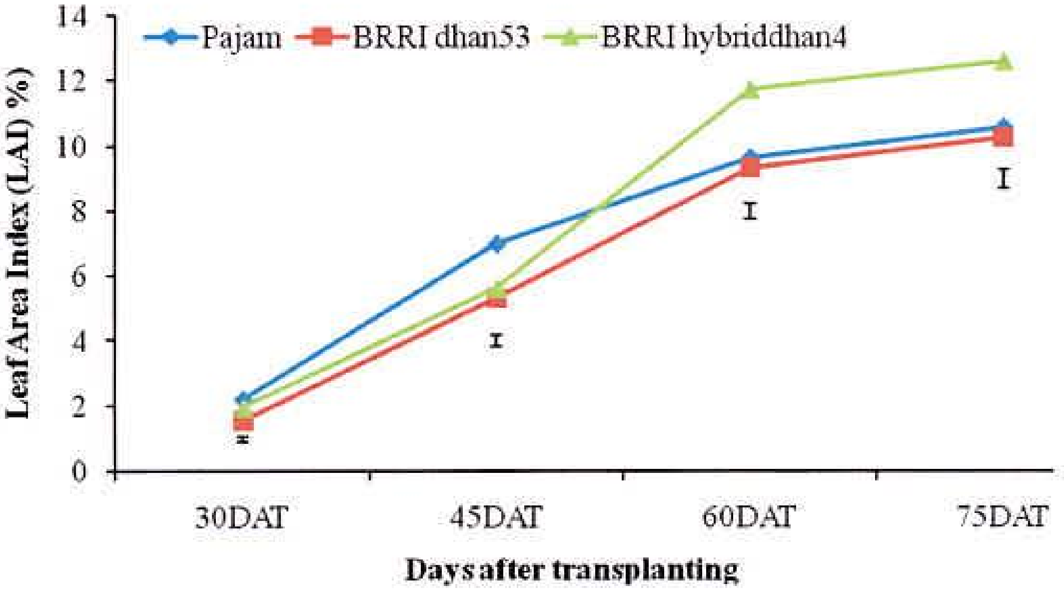


Figure 4. Effect of variety on leaf area index at different growth duration of transplanted aman rice ($LSD_{0.05}$ value 0.07, 0.17, 0.25 and 0.29 at 30, 45, 60 and 75 DAT, respectively) Vertical bars indicate the LSD values.

4.4.2 Effect of treatments

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 T3 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).

Table 7. Effect of seedling hardening treatment on leaf area index at different growth duration of transplanted aman rice

	Leaf area index at different DAT			
Treatments	**30**	**45**	**60**	**75**
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 latter(s) are statistically similar and those having dissimilar latter(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

4.4.3 Interaction effect of variety and treatments

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 8. Combined effect of variety and treatments on Leaf area index (LAI) of transplanted aman rice at different DAT

Variety	Treatment	Leaf area index (LAI)			
		30DAT	45DAT	60DAT	75DAT
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 latter(s) are statistically similar and those having dissimilar latter(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.

4.5 Dry matter production

4.5.1 Effect of variety

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 (2006) also observed that hybrid rice produced more dry matter in plant than inbred varieties.

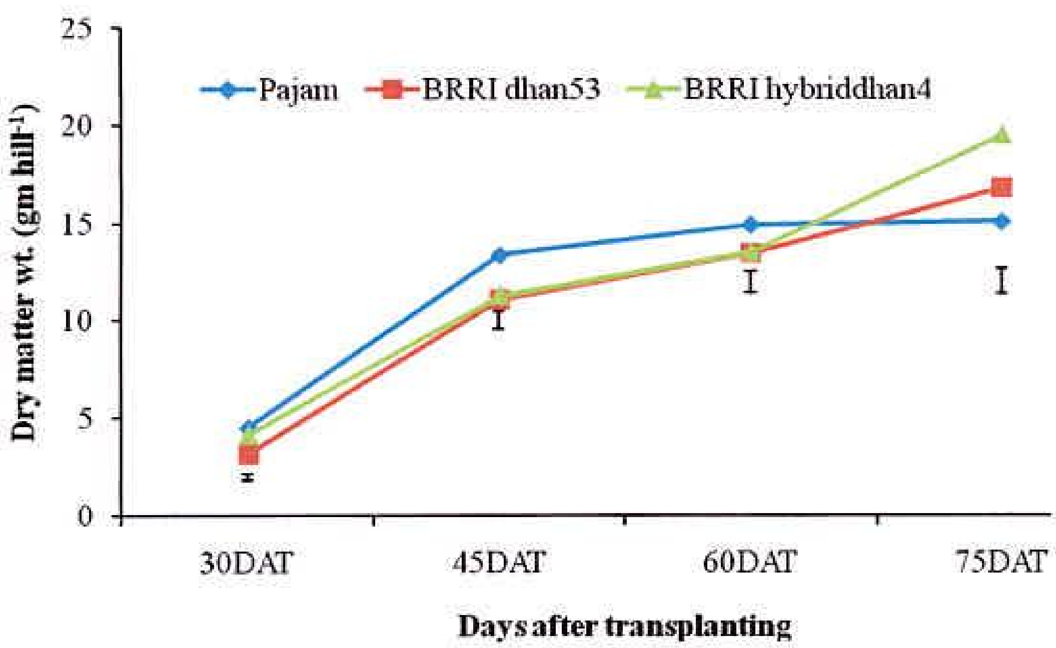


Figure 5. Effect of variety on total dry matter production of transplanted aman rice at different days after transplanting ($LSD_{0.05}$ value 0.15, 0.46, 0.54 and 0.66 at 30, 45, 60 and 75 DAT, respectively) Vertical bars indicate the LSD values

4.5.2 Effect of treatments

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.

Table 9 Effect of seedling hardening treatment on dry matter production at different growth duration of transplanted aman rice

	Total dry weight (g hill^{-1}) at different DAT			
Treatments	**30**	**45**	**60**	**75**
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 latter(s) are statistically similar and those having dissimilar latter(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

4.5.3 Interaction effect of variety and treatments

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 (14.20g $hill^{-1}$), V_3T_3(13.73g $hill^{-1}$) and V_1T_2(13.59g $hill^{-1}$) 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(9.27g $hill^{-1}$), V_3T_4 (9.63g $hill^{-1}$),V_2T_2 (10.33g $hill^{-1}$) V_1T_1 (10.63g $hill^{-1}$), V_3T_2 (10.76g $hill^{-1)}$. 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 (11.77g $hill^{-1}$) of inbred , (12.30g $hill^{-1}$) hybrid and local (12.7g $hill^{-1}$) variety and V_3T_4 (12.73g $hill^{-1}$), V_2T_2 (13.17g $hill^{-1}$), 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(20.30g $hill^{-1}$), V_3T_2(19.30g $hill^{-1}$), V_3T_4(18.90g $hill^{-1}$), V_1T_3(18.70g $hill^{-1}$) 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(13.20g $hill^{-1}$), V_2T_4(13.37g $hill^{-1}$), V_1T_2(13.80g $hill^{-1}$) and V_2T_1 (15.07g $hill^{-1}$).

Table 10. Interaction effect of treatment on dry matter production on the performance of transplanted aman rice at different DAT

Variety	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 latter(s) are statistically similar and those having dissimilar latter(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.

4.6 Yield attributes

4.6.1 Number of effective tillers hill^{-1}

4.6.1.1 Effect of variety

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 (7.127) was measured from BRRI dhan53 and the lowest effective tiller (6.480) was obtained from Pajam .

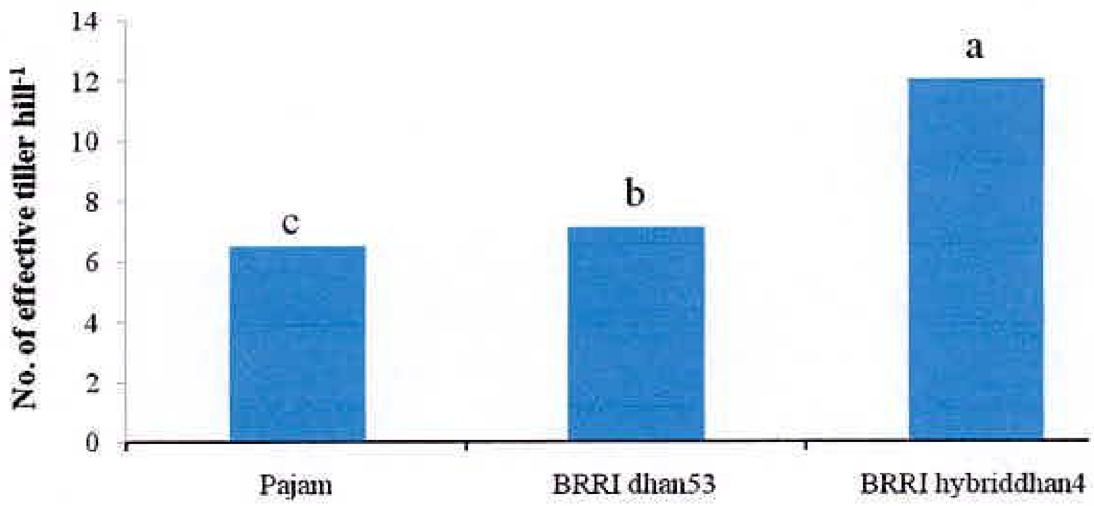


Figure 6. Effect of variety on effective tillers hill^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.1.2 Effect of treatments

Storage in open field condition gave the highest effective tiller (9.8111) (Table 11). The second highest effective tiller (9.0889) was obtained from the effect of Storage in cool air condition .Direct transplanting of seedling in the field gave the lowest effective tiller (7.322).

Table 11. Effect of hardening treatment on effective tillers hill^{-1} of transplanted aman 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)	9.811a
Storage in water (T_4)	7.844c
Storage in cool air (T_5)	9.089b
$LSD_{(0.05)}$	**0.51**
CV (%)	**6.16**

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

4.6.1.3 Interaction effect of variety and treatments

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 (4.633) 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.

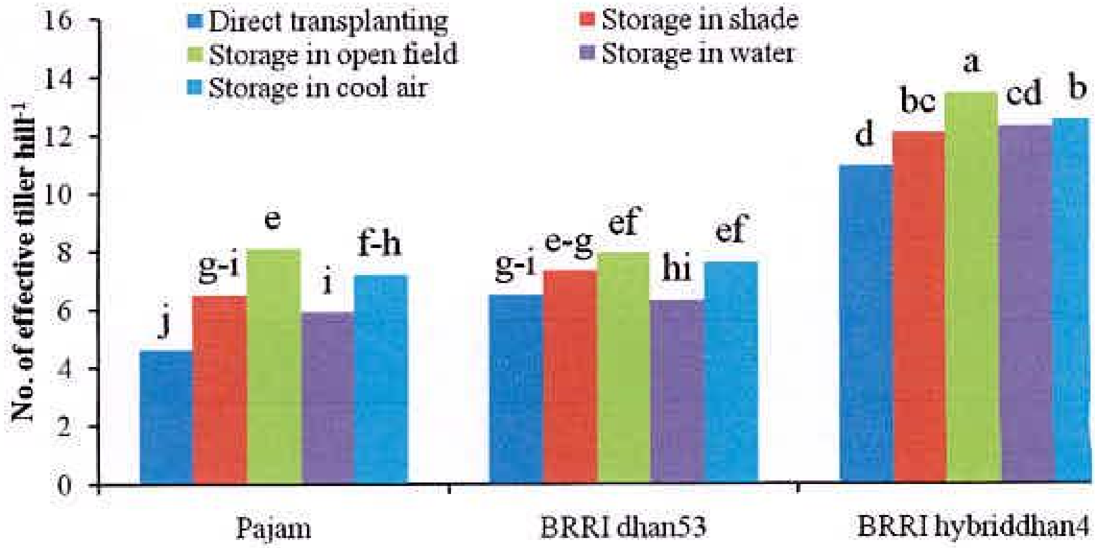


Figure 7. Interaction effect of variety and hardening treatment on number of effective tillers hill^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.2 Non-effective tillers hill^{-1}

4.6.2.1 Effect of variety

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.

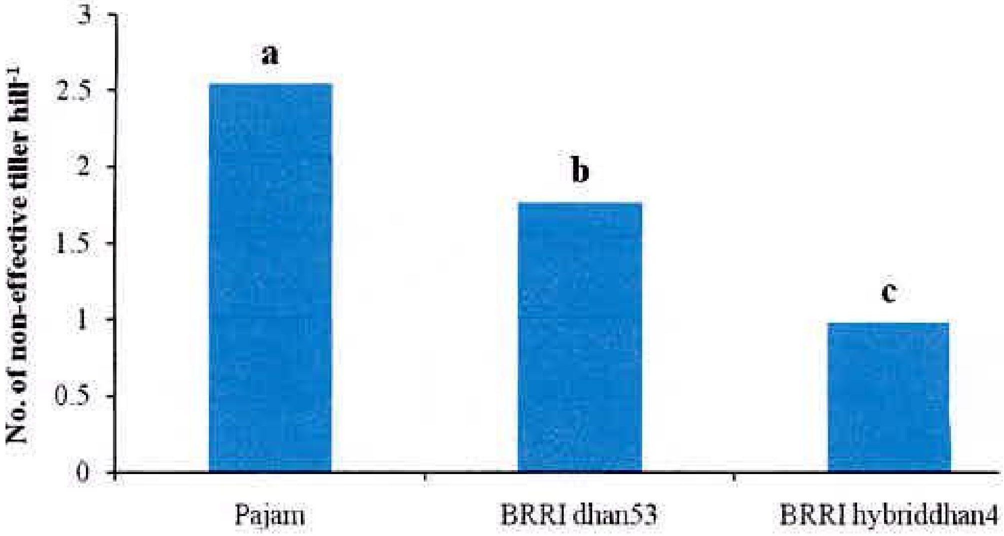


Figure 8. Effect of variety on non-effective tiller hill^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.2.2 Effect of treatments

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.

Table 12. Effect of hardening treatment on non-effective tillers hill^{-1} of transplanted aman 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 latter(s) are statistically similar and those having dissimilar latter(s) different significantly at 0.05 level of probability following LSD test

4.6.2.3 Interaction effect of variety and treatments

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.

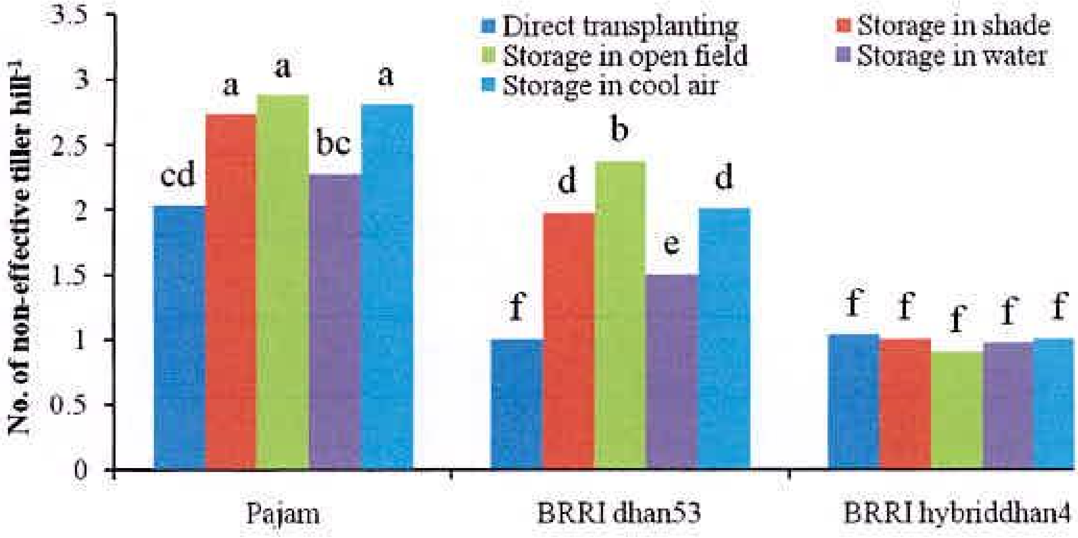


Figure 9. Interaction effects of variety and hardening treatment on number of non-effective tillers hill^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.3 Panicle length

4.6.3.1 Effect of variety

The panicle length varied significantly due to variety shown in Fig. 10. It was observed that BRRI hybriddhan4 produced significantly longer (26.23 cm) panicle. The second highest panicle length (23.03 cm) was measured from BRRI dhan53 and the shortest panicle length (22.77 cm) was measured from Pajam.

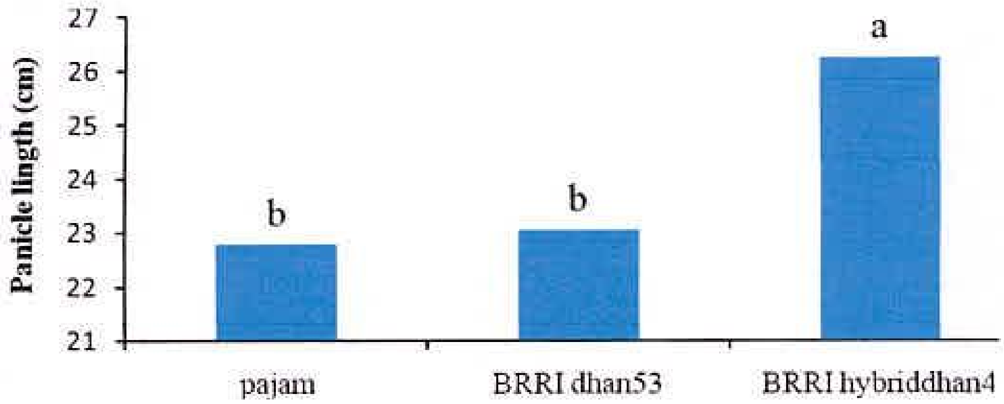


Figure 10. Effect of variety on panicle length of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.3.2 Effect of treatments

The panicle length varied significantly due to different treatments shown in (Fig. 11). It was observed that the longest panicle length (26.42 cm) was observed from the treatment of Storage in open field which was statistically similar with the treatment of cool air condition. The shortest (21.12 cm) panicle length was observed from control treatment.

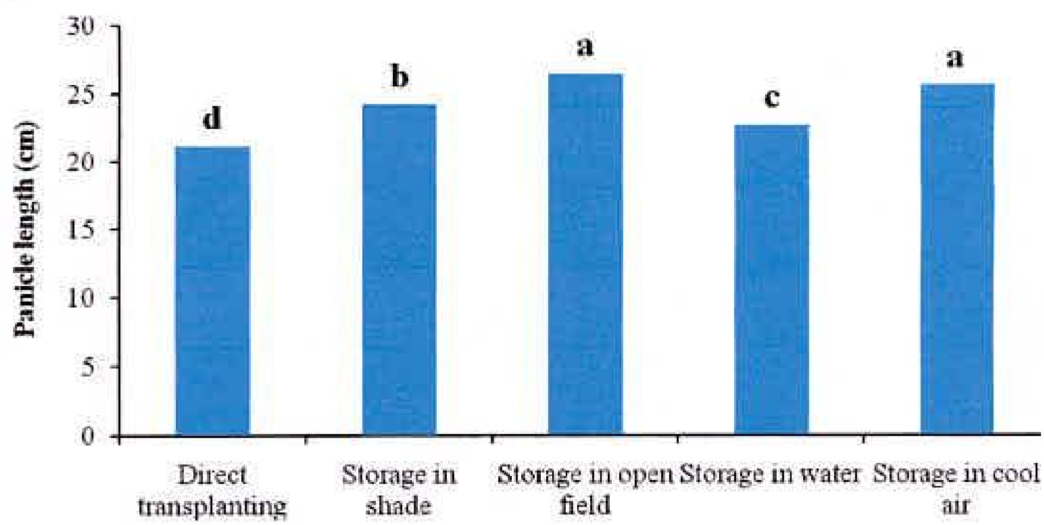


Figure 11. Effect of different hardening treatment of seedling methods on panicle length of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.3.3 Interaction effect of variety and treatments

Panicle length was significantly affected by the interaction of variety and different treatments condition. Longest (28.63 cm) panicle was observed from the combination BRRI hybriddhan4 with Storage in open field condition which was statistically similar with the combination of BRRI hybriddhan4 and storage in shade and storage in cool air condition. Second highest panicle length (27.56 cm) was obtained from the combination of BRRI hybriddhan4 with Storage in cool air and shorter (18.90 cm) was found from the combination of Pajam with direct transplanting.

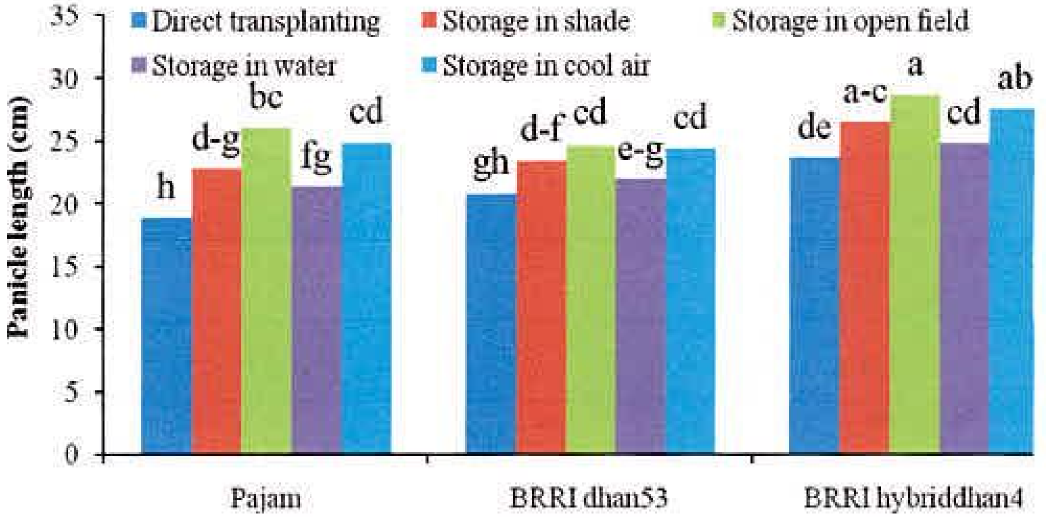


Figure 12. Interaction effect of variety and different hardening treatment on panicle length of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.4 Filled grains panicle^{-1}

4.6.4.1 Effect of variety

Significant variation was observed in filled grain due to the effect of variety shown in Fig. 13. The highest filled grain (129.50) was found in BRRI hybriddhan4. The second highest filled grain (112.46) was obtained from Pajam .The lowest filled grain (90.19) was gained from BRRI dhan53.

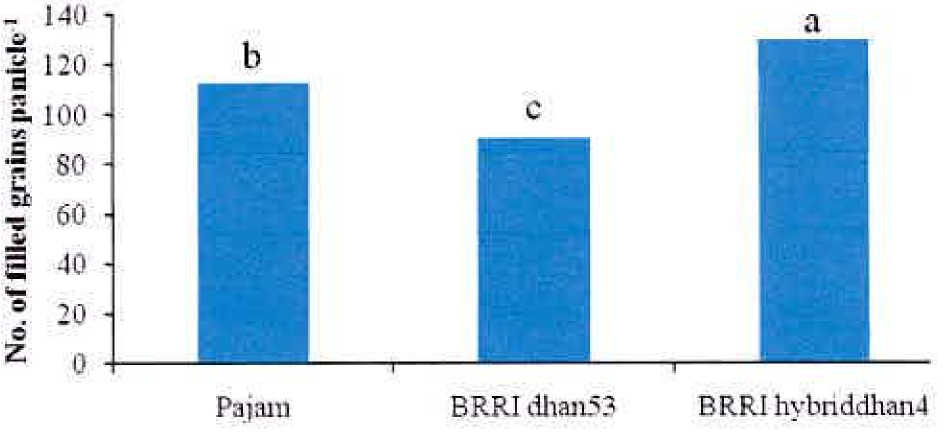


Figure 13. Effect of variety on filled grain panicle^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.4.2 Effect of treatments

Significant variation was found in filled grain due to the effect of different treatments (Fig. 14). The highest filled grain (125.48) was obtained from the effect of Storage in open field condition .The lowest filled grain (94.86) was obtained from direct transplanting.

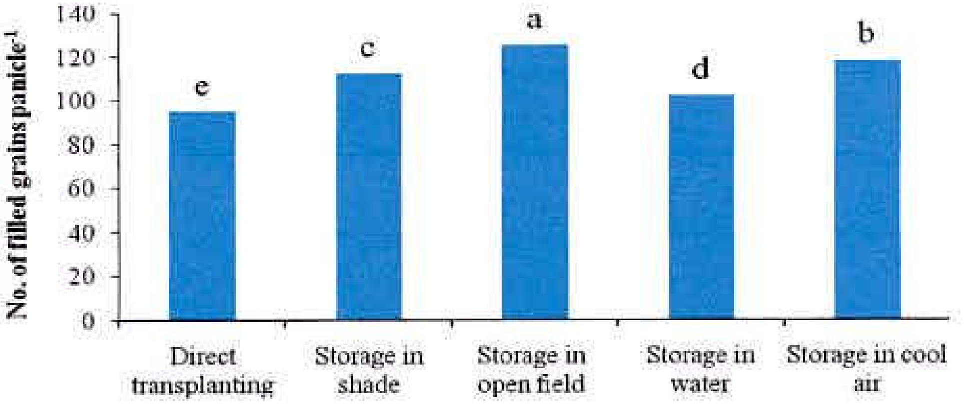


Figure 14. Effect of different treatments on filled grain panicle^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.4.3 Interaction effect of variety and treatments

Significant variation was obtained in filled grain due to the interaction effect of variety and treatments (Fig. 15). The highest filled grain (147.67) was obtained from the interaction effect of BRRI hybriddhan4 with Storage in open field condition. The lowest filled grain (75.13) was found from the interaction effect of BRRI dhan53 with direct transplanting which was statistically similar with storage in water treatment of Pajam variety and storage in open field and cool air treatment of BRRI dhan53.

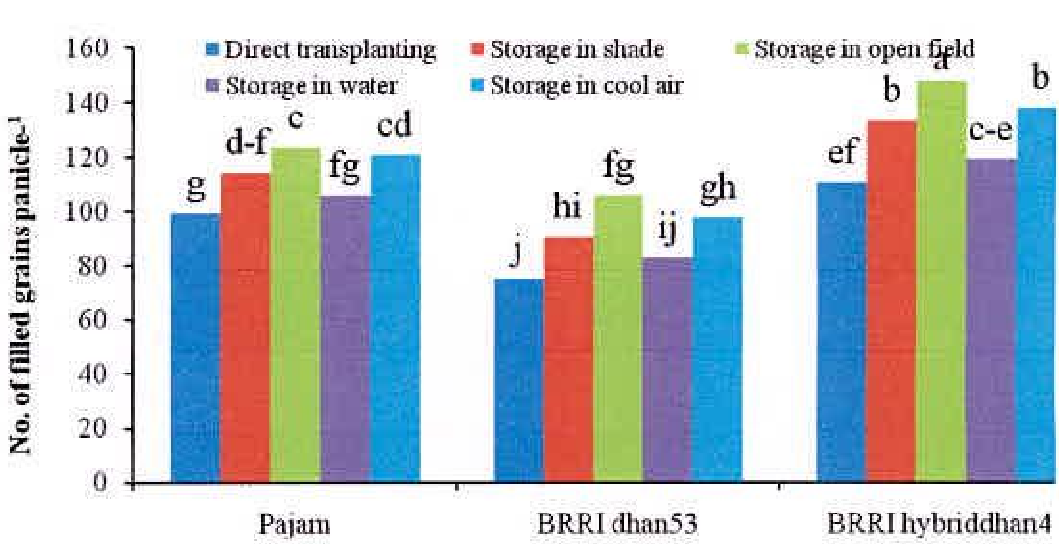


Figure 15. Interaction effect of variety and hardening treatment on number of filled grains panicle^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.5 Unfilled grains panicle^{-1}

4.6.5.1 Effect of variety

Significant variation was obtained in unfilled grain due to the effect of variety (Fig. 16). BRRI hybriddhan4 produced highest unfilled grain (334.25). The second highest unfilled grain (17.33) was obtained from BRRI dhan53 and lowest unfilled grain (13.77) from Pajam.

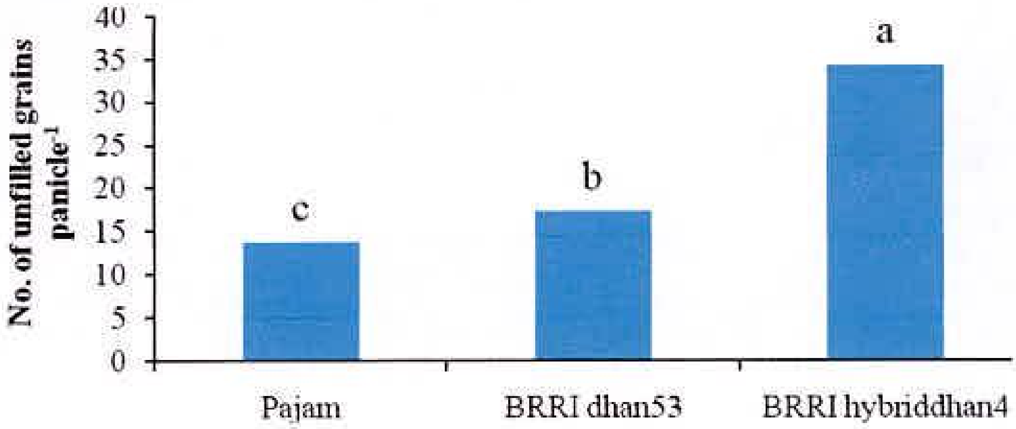


Figure 16. Effect of variety on unfilled grains panicle^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.5.2 Effect of treatments

Effect of treatments showed significant variation in unfilled grain (Fig. 17). Storage in open field condition gave highest unfilled grain (26.06) and the lowest unfilled grain (18.73) was obtained from Direct transplanting which was statistically similar with Storage in water condition.

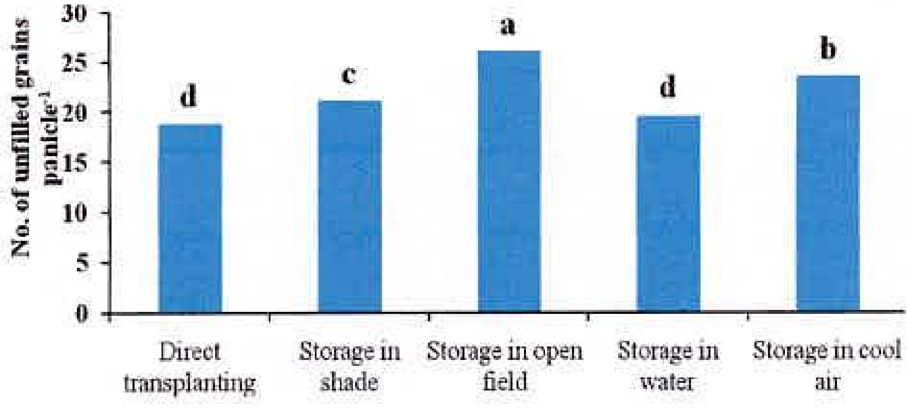


Figure 17. Effects of seedlings hardening treatments on unfilled grain panicle^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.5.3 Interaction effect of variety and treatments

Significant variation was obtained in unfilled grain due to the interaction effect of variety and different seedling hardening treatments shown in Fig. 18. Interaction effect of BRRI hybriddhan4 with Storage in open field condition gave highest unfilled grain (40.27). The lowest unfilled grain (10.20) was found from the interaction effect of Pajam with Direct transplanting condition.

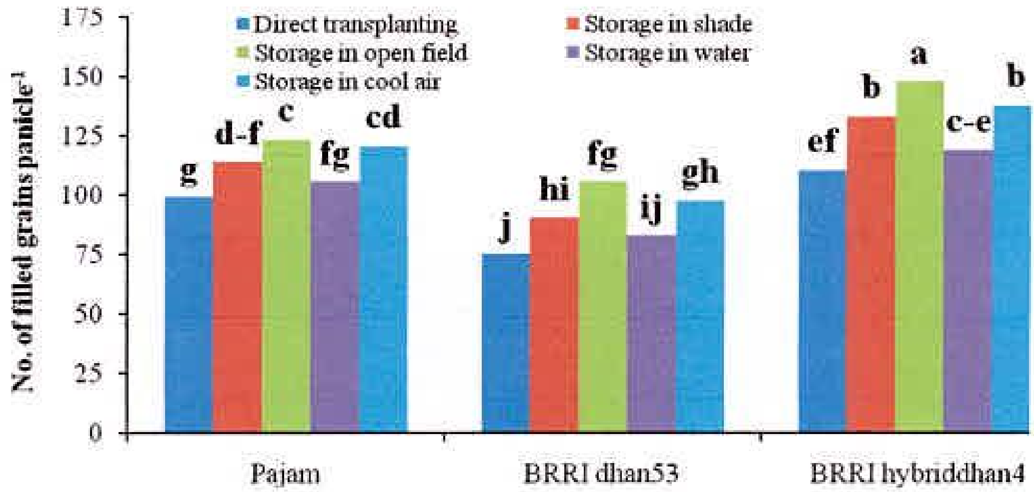


Figure 18. Interaction effect of variety and hardening treatment on number of unfilled grains panicle^{-1} of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.6.6 1000 grain weight

4.6.6.1 Effect of variety

Weight of 1000 grains showed significant variation among the different varieties. BRRI hybriddhan4 produced highest 1000 grain weight (25.19 g). The second highest 1000 grain weight (22.31 g) was found in BRRI dhan53 (Fig. 19). The lowest 1000 grain weight (17.83 g) was obtained from Pajam.

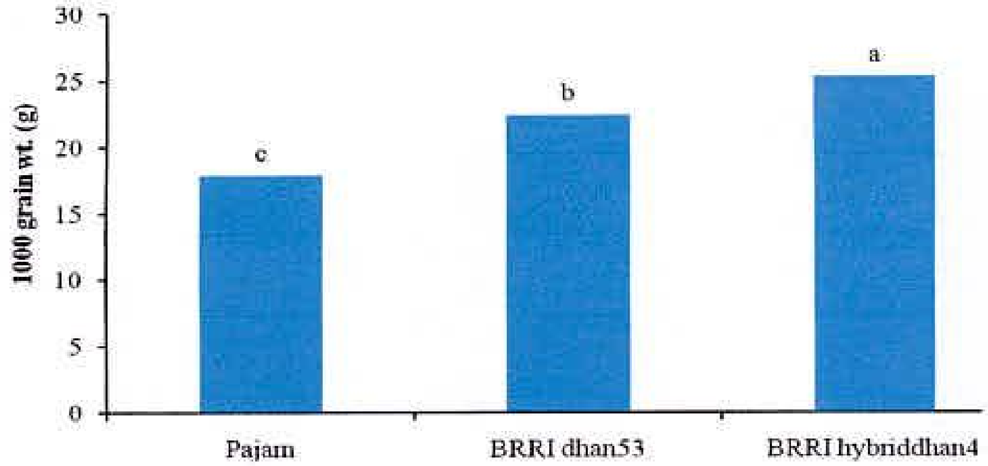


Figure 19. Effect of variety on filled 1000 grain weight of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.6.2 Effect of treatments

Effect of treatments showed significant variation in 1000 grain weight. Storage in open field condition gave the highest 1000 grain weight (23.38 g) (Fig. 20). The lowest 1000 grain weight (20.64 g) was found from direct transplanting which was statistically similar with storage in water condition.

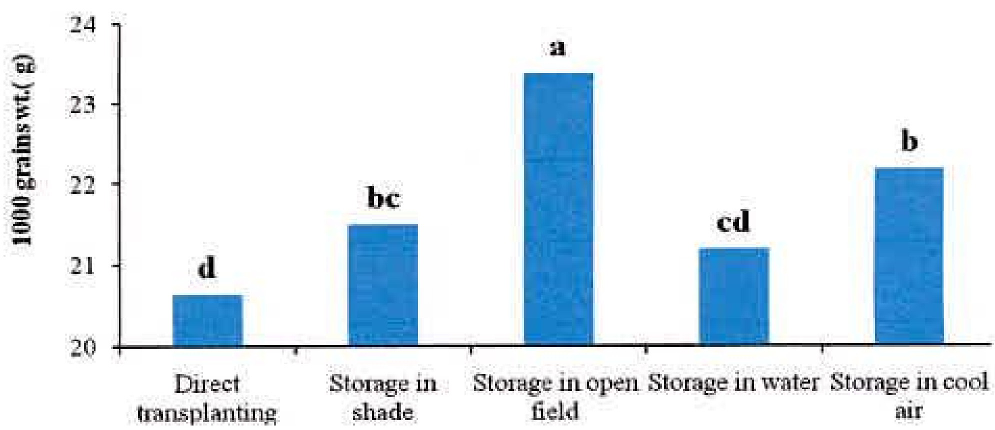


Figure 20. Effects of treatments on 1000 grain weight of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.6.6.3 Interaction effect of variety and treatments

Interaction effect of variety and treatments showed significant variation in 1000 grain weight shown in Fig. 21. The highest grain weight (25.83 g) was found from the interaction effect of BRRI hybriddhan4 and open field condition which was statistically similar with hardening treatment of kept in water , cool air, shade and control condition of BRRI hybriddhan4 variety. The second highest grain weight (23.13 g) was obtained from the interaction effect of BRRI dhan53 with open field condition which was statistically similar with other treatments of BRRI dhan53 variety. The lowest grain weight (15.03 g) was found with the interaction effect of Pajam with direct transplanting.

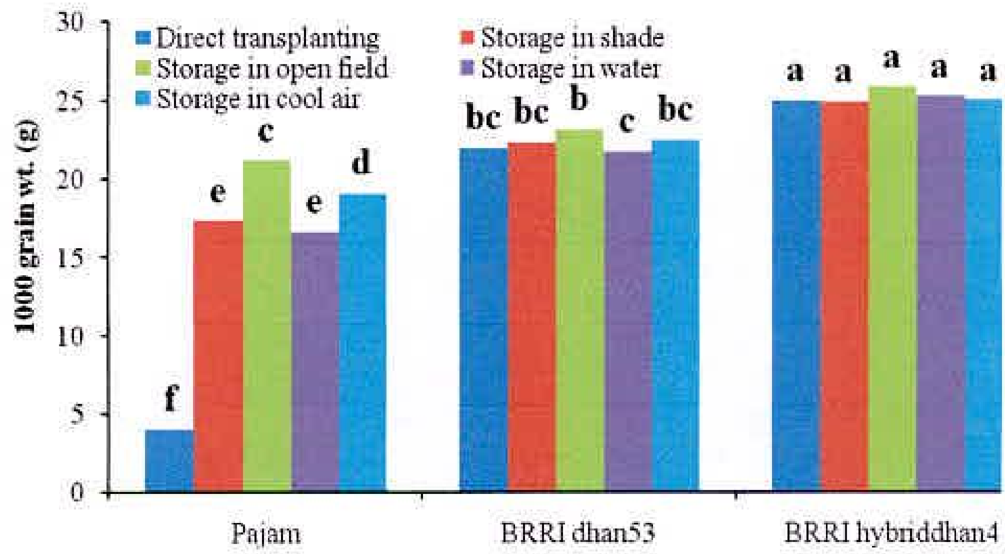


Figure 21. Interaction effect of variety and hardening of seedling on weight of 1000 grains of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.7 Grain yield

4.7.1 Effect of variety

Grain yield varied significantly for different varieties shown in Fig. 22. The highest grain yield (7.01t ha^{-1}) was recorded by BRRI hybriddhan4. The second highest grain yield (3.25 t ha^{-1}) was recorded from Pajam. The lowest grain yield (2.99 t ha^{-1}) was recorded from BRRI dhan53. The results are in conformity with the observation of Obaidullah (2007) in hybrid rice and Main (2006) in Transplanted aman rice.

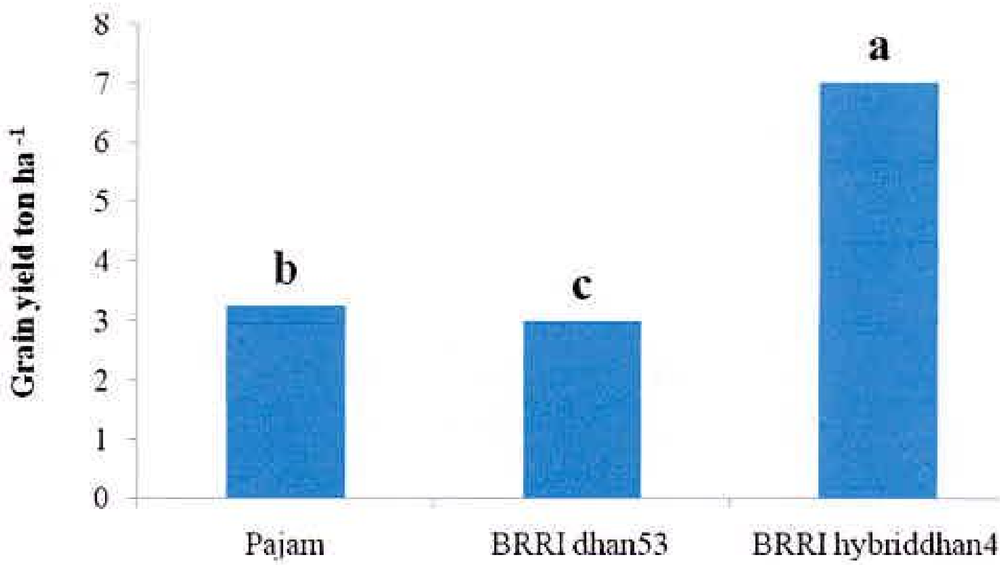


Figure 22. Effect of variety on grain yield of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.7.2 Effect of treatments

Significant variation was observed for grain yield due to different treatments (Fig. 23). The highest yield (4.85 t ha^{-1}) was recorded from open field storage condition and the lowest yield (3.93 t ha^{-1}) was obtained from direct transplanting treatment condition.

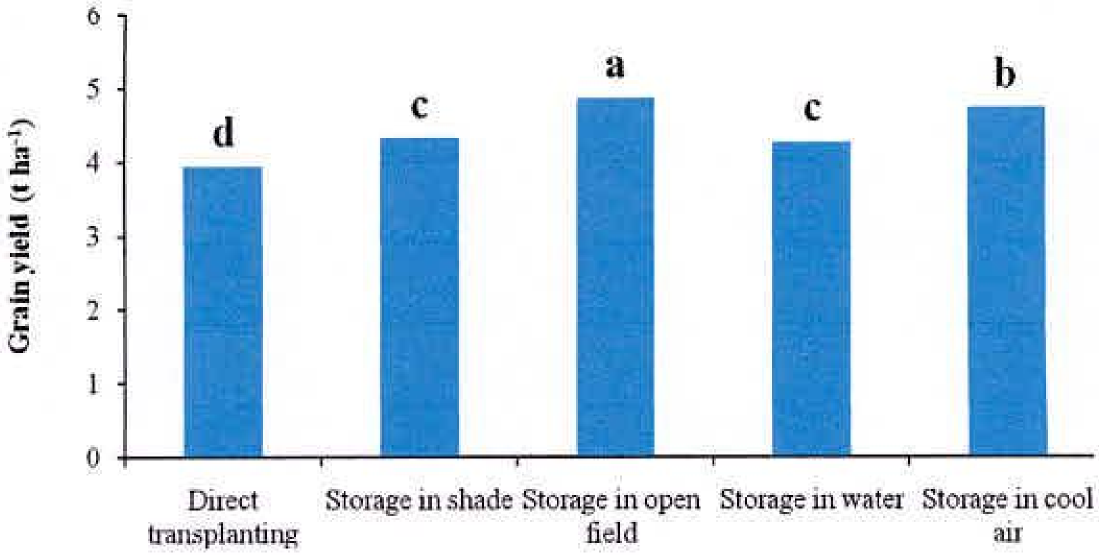


Figure 23. Effect of treatments on grain yield of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.7.3 Interaction effect of variety and treatments

The grain yield varied significantly due to different varietal and treatment combinations (Fig. 24). The highest grain yield (7.26 t ha^{-1}) was recorded from BRRI hybriddhan4 and open field storage treatment condition which was statistically similar with BRRI hybriddhan4 and storage in cool air treatment. The lowest grain yield (2.31 t ha^{-1}) was recorded from BRRI dhan53 and direct transplanting treatment combination.

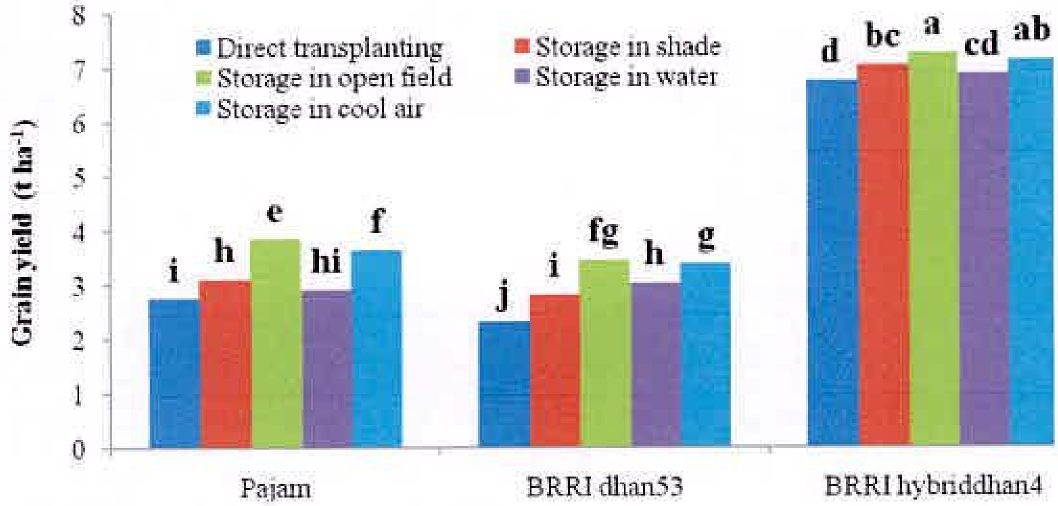


Figure 24. Interaction effect of variety and hardening treatment of seedling on grain yield of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.8 Straw yield

4.8.1 Effect of variety

There was significant variation observed for straw yield due to varietal variation (Fig. 25). BRRI hybriddhan4 recorded the highest straw yield (5.91 t ha^{-1}) and the second highest straw yield (3.76 t ha^{-1}) was obtained from BRRI dhan53. Pajam recorded the lowest (3.47 t ha^{-1}) straw yield.

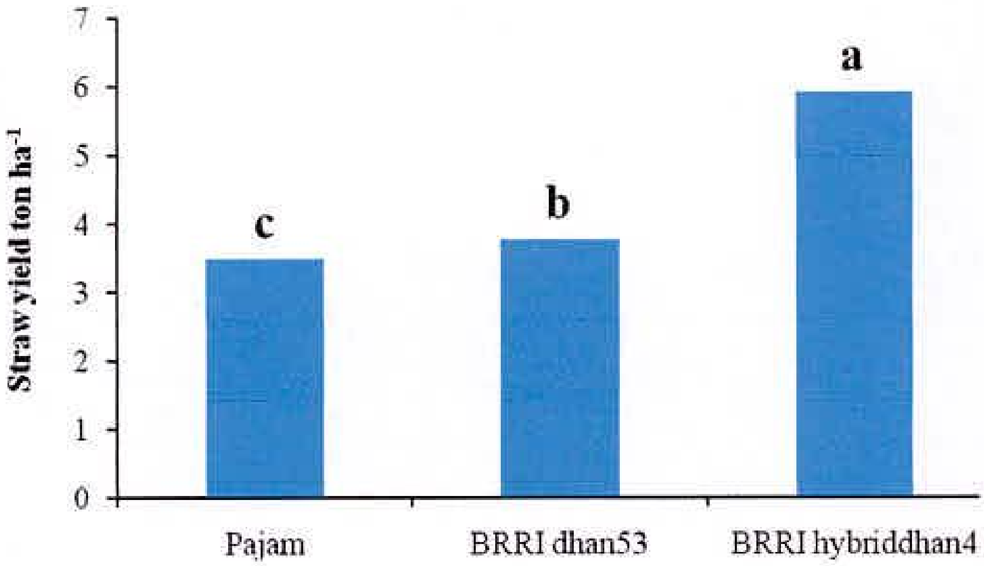


Figure 25. Effect of variety on straw yield of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.0 applying LSD test

4.8.2 Effect of treatments

Significant variation was also observed due to different treatments (Fig. 26). Highest straw yield (4.87 t ha^{-1}) was recorded from open field treatment and the lowest (3.97 t ha^{-1}) was recorded from direct transplanting and storage in water treatment.

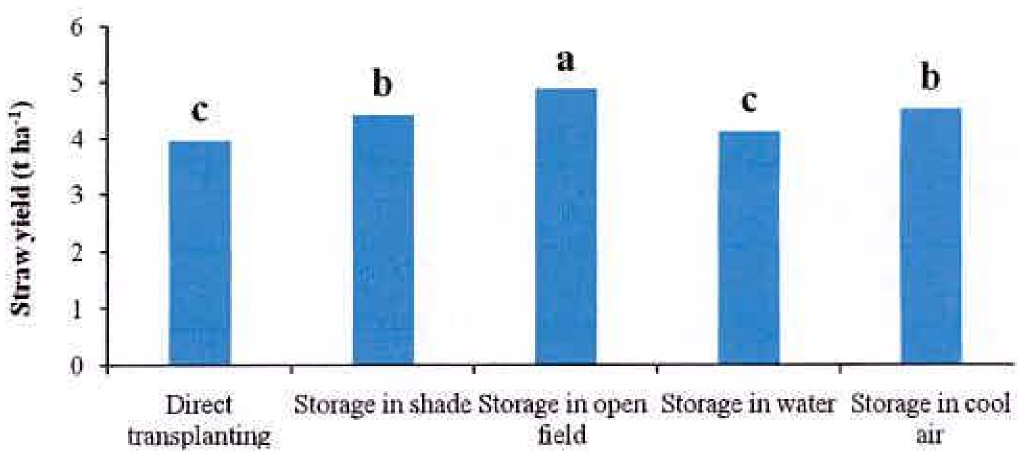


Figure 26. Effect of hardening treatments on straw yield of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.8.3 Interaction effect of variety and treatments

The straw yield varied significantly due to different varietal and treatment combinations (Fig. 27). The highest straw yield (6.77 t ha^{-1}) was obtained from the combination BRRI hybriddhan4 with open field treatment condition. The lowest (3.17 t ha^{-1}) was found from the combination BRRI dhan53 with direct transplanting treatment condition which was statistically similar with same treatment of local variety and storage in water condition with BRRI dhan53 variety.

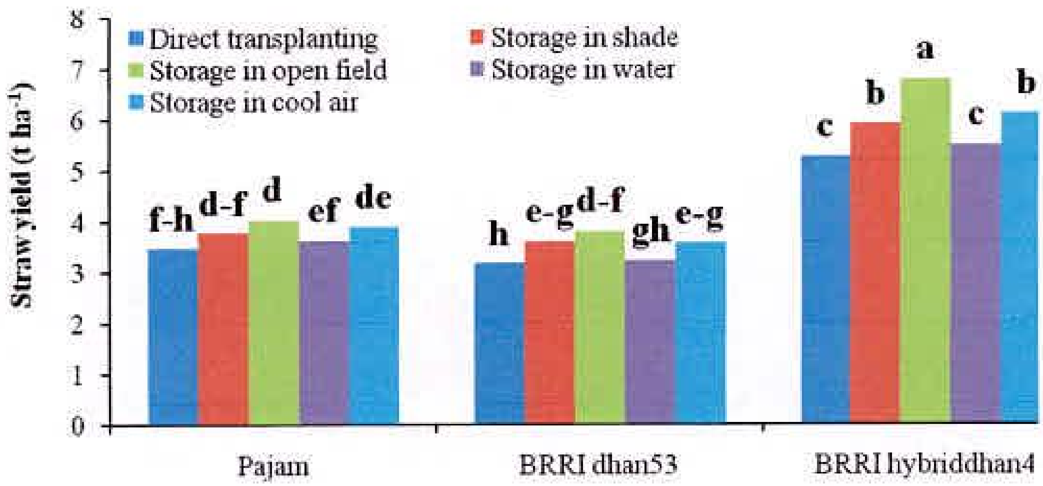


Figure 27. Interaction effect of variety and hardening treatment of seedling on straw yield of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.9 Biological yield

4.9.1 Effect of variety

Biological yield was significantly influenced by the variety (Fig. 28). Numerically higher biological yield (12.92 t ha^{-1}) was obtained from the hybrid variety BRRI hybriddhan4 and lower (6.467 t ha^{-1}) from the inbred variety BRRI dhan53. This might be hybrid variety produced higher grain and straw yield compared to BRRI dhan53. Obaidullah (2007) and Main (2006) also reported a significant differences in biological yield of rice with different rice varieties.

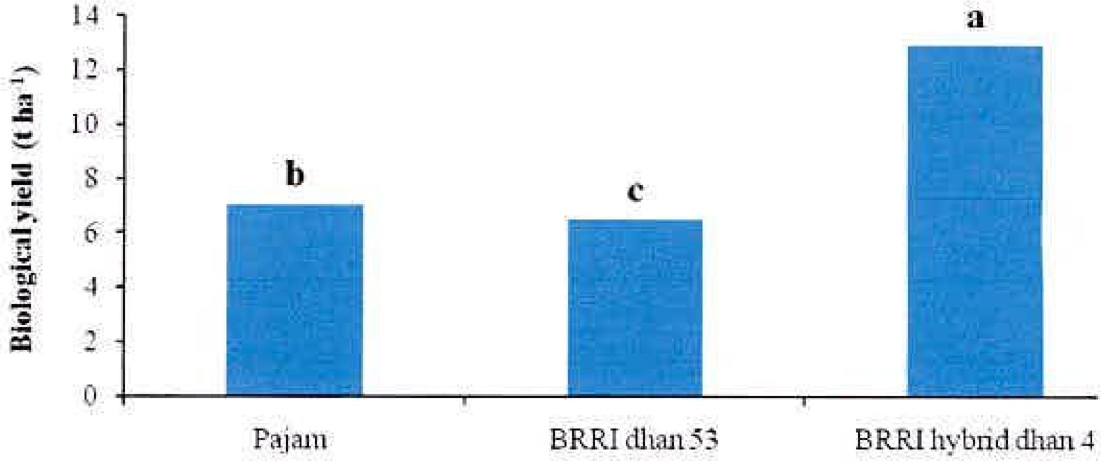


Figure 28. Effect of variety on biological yield of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.0 applying LSD test

4.9.2 Effect of treatments

Biological yield was significantly influenced by the pre-planting hardening treatment (Fig. 29). The highest biological yield (9.72 t ha^{-1}) was obtained from the storage in open field seedlings. Open field seedlings produced the highest grain yield and straw yield which resulted in the highest biological yield. The lowest biological yield (7.90 t ha^{-1}) was found from direct transplanting seedling. This was due to the lowest amount of grain and straw yield in direct transplanting seedling.

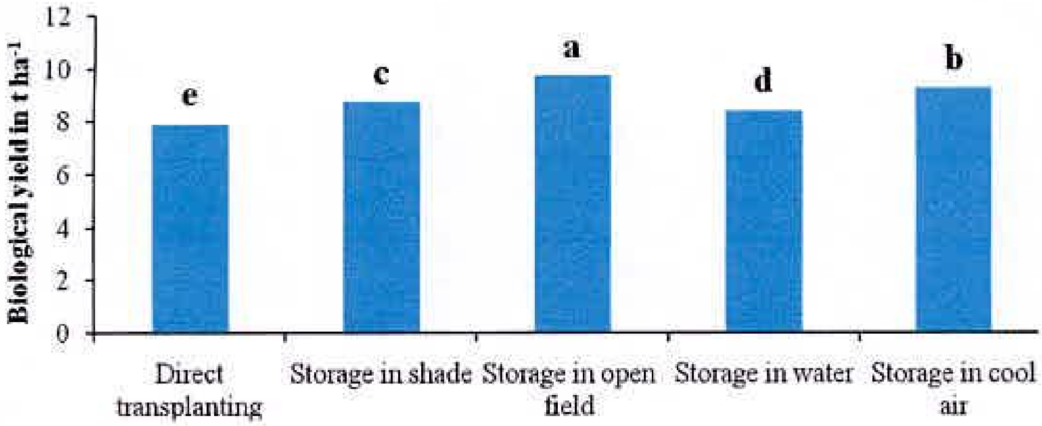


Figure 29. Effect of seedling hardening treatments of biological yield on transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.9.3 Interaction effect of treatments and variety on T.aman rice

Interaction effect between variety and pre planting treatment was significant in respect of biological yield (Fig. 30). The highest biological yield (14.03 t ha^{-1}) was observed in storage in open field treatment seedlings of the hybrid variety BRRI hybriddhan4. The lowest yield was observed in control condition (6.21 t ha^{-1}) of BRRI dhan53 variety.

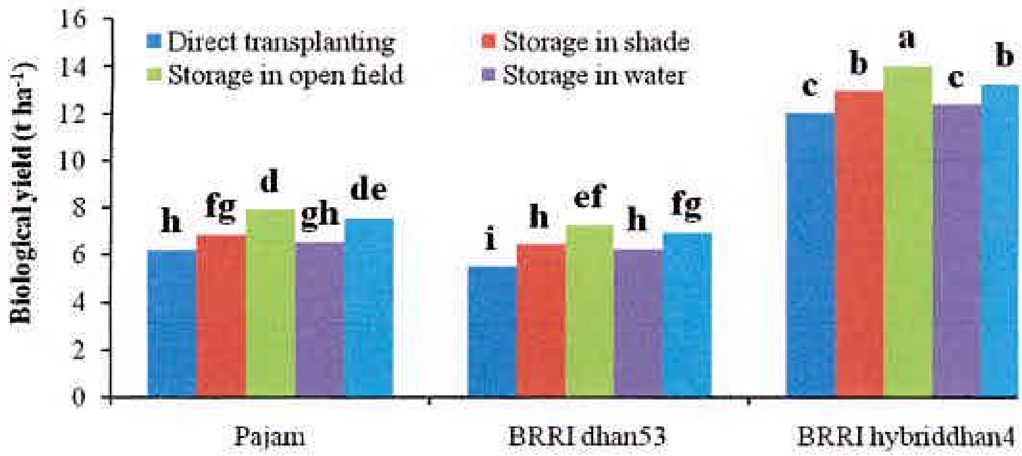


Figure 30. Interaction effect of variety and hardening treatment of seedling on biological yield (t ha^{-1}) of inbred and hybrid aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

4.10 Harvest index (%)

4.10.1 Effect of variety

Harvest index was significantly influenced by the variety (Fig. 31). Numerically higher harvest index (54.38%) was obtained from the hybrid variety BRRI hybriddhan4 and lower (46.12%) from the inbred variety BRRI dhan53 which is statistically similar with local variety Pajam (46.2 %). However this finding was agreed with Debnath (2010) and Ahmed (2006) who observed significant difference between inbred and hybrid variety in respect of harvest index where the higher harvest index was obtained from the hybrid variety than that of inbred variety.

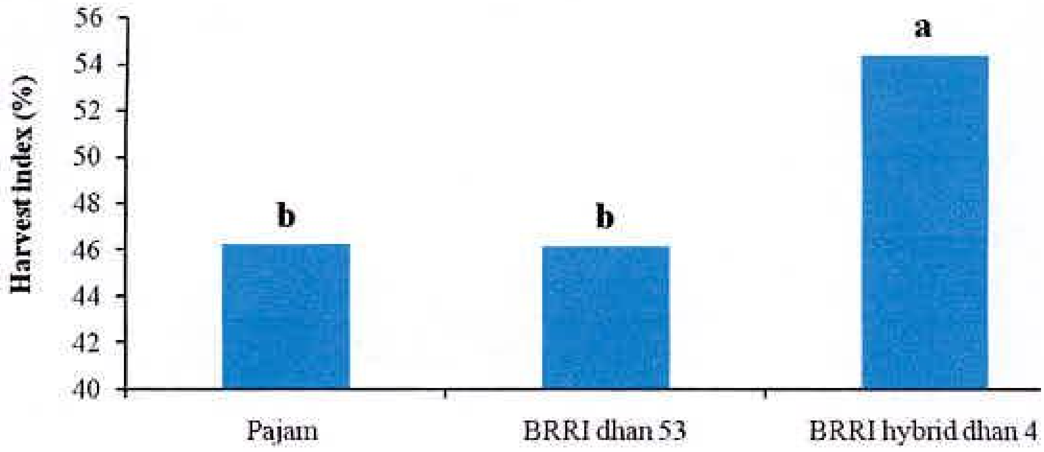


Figure 31. Effect of variety on Harvest index (%) of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.10.2 Effect of treatments

Harvest index was significantly influenced by the pre planting seedling treatments. Numerically the highest harvest index (50.32%) was obtained from the condition of storage in cool air seedling which was statistically similar with storage in water (49.45 %) and storage in open air condition. The lowest harvest index (47.53%) was found from direct transplanting seedlings which were statistically similar with storage in shading condition (47.80%).

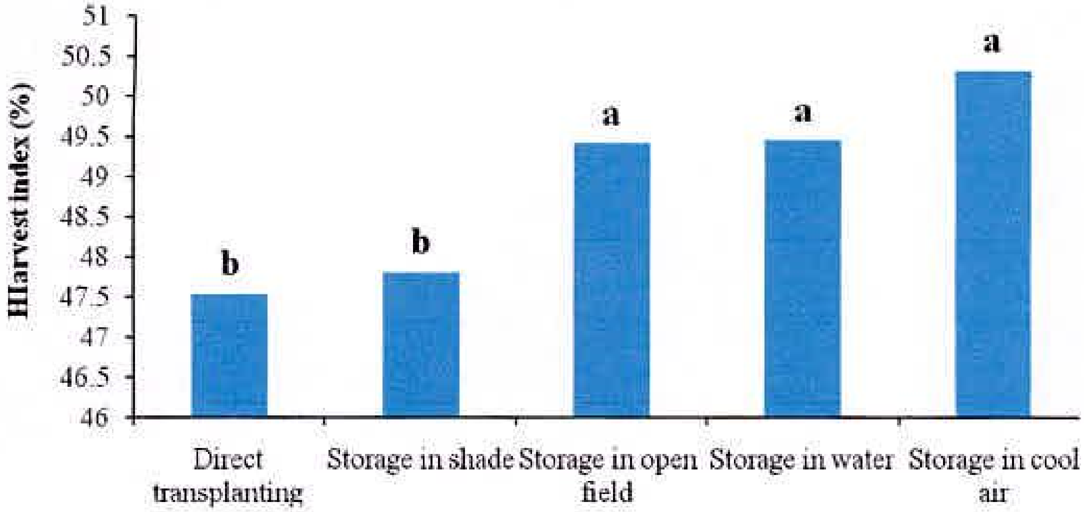


Figure 32. Effect of pre-planting seedling treatment on Harvest index (%) of transplanted aman rice. Bars with similar letter do not differ significantly at p≤0.05 applying LSD test

4.10.3 Interaction effect of variety and hardening treatments

Interaction effect between variety and pre planting hardening treatment was significant in respect of harvest index (Fig. 33). The highest harvest index (56.18%) was observed in direct transplanting seedlings of the hybrid variety, which was statistically similar with storage in water (55.57%), storage in shade (54.43%), and directs transplanting (53.95%) and storage in cool air treatment of hybrid variety. The lowest harvest index (42.20%) was observed in control treatment of the inbred variety, which was statistically similar with control treatment (44.22%) of local variety and storage in water condition (43.80%) of inbred variety.

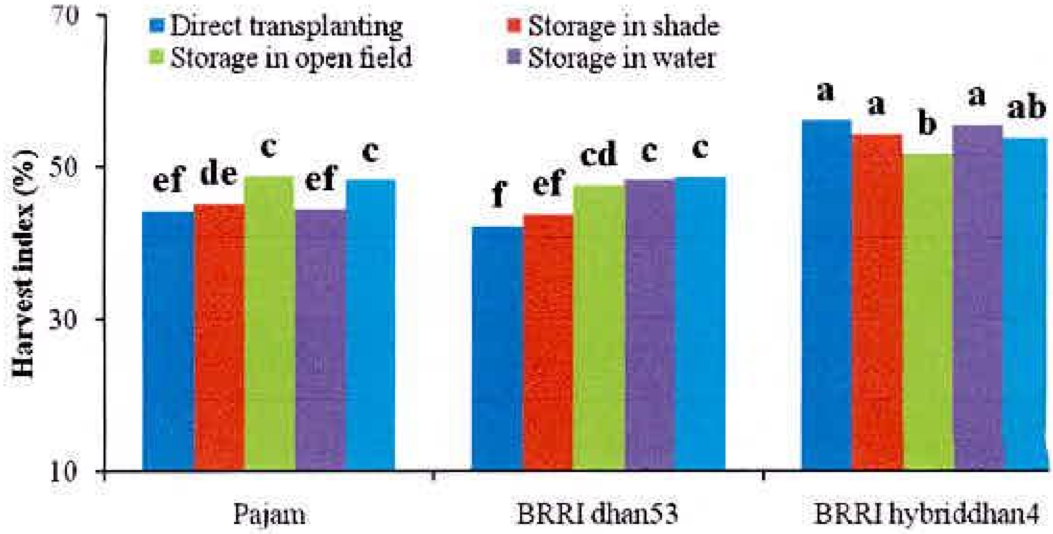


Figure 33. Interaction effect of variety and hardening treatment of seedling on Harvest index (%) of transplanted aman rice. Bars with similar letter do not differ significantly at $p \leq 0.05$ applying LSD test

Chapter 5

SUMMARY AND CONCLUSION

The experiment was with a view to investigate the pre-planting hardening of seedling on the performance of inbreed and hybrid aman rice at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during aman season (July to December, 2013). The experiment was carried out with three varieties *i.e.* BRRI dhan53, BRRI hybriddhan4, and Pajam in the main plot and five seedling hardening treatment methods viz. direct transplanting (T_1), storage in shade condition for three days (T_2), storage in open field condition for three days (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 of the experiment showed that hardening treatment of seedling had a significant influenced on growth characters, yield contributing characters and yield. It revealed that open field seedling treatment gave the longest plant height at 30, 45, 60,75 days growth duration. Hardening treatment showed significant variation of tiller number at 30, 45, 60 and 75 DAT. In case of LAI at 30, 45 60and 75 days maximum LAI found in open field storage condition. In respect of dry matter production all time open field storage treatment showed the highest dry weight compare to direct transplanting, storage in shed, storage in water and storage in cool air condition.. Maximum number of effective tillers hill^{-1}, was found at open field storage condition(9.81) and minimum was at from direct transplanting of seedling (7.32). Filled grains panicle^{-1} was the highest (125.48) at open field storage condition compare to other hardening treatment. Thousand grains weight was maximum at open field storage condition (23.38g) whereas other hardening treatment showed minimum grain weight. Grain yield was the highest in open field treatment

(4.85 t ha^{-1}) and th lowest yield (3.93 t ha^{-1}) was observed indirect transplanting of seedling treatment. The highest harvest index (50.32%) was observed in cool air condition that was statistically similar with storage in water and storage in open air condition and the lowest (47.80%) in storage in shade and direct transplanting condition.

Interaction effect of seedling hardening treatment and variety on growth as well as yield and yield contributing characters inbreed variety with all hardening treatment showed variable responses and most of the cases BRRI hybrid dhan4 stored in open field before transplanting showed the best result.

In this experiment three different varieties were used to observe their response under field condition when the transplanted seedlings were stored previously in different condition. From the results local (Pajam), HYV (BRRI dhan53) and hybrid (BRRI hybriddhan4) showed differences in their growth and yield performances. In open field condition, Pajam variety was significantly increased in plant height, number of effective tillers, leaf area index (LAI) and total dry matter (TDM) at 30DAT and 45DAT, respectively but later on BRRI hybriddhan4 showed the highest result. Different seedling hardening methods viz. direct transplanting (T_1), storage in shade condition for three days (T_2), storage in open field condition for three days (T_3), storage in water condition for three days (T_4) and storage in cool air condition for 24 hours (T_5) showed variable responses under subsequence field condition. Yield attributing parameters, such as panicle length, grain number $panicle^{-1}$, 1000 grain weight and yield were improved due to the treatments. The highest grain yield (7.26 t ha^{-1}) was in BRRI hybriddhan4 under open field storage condition. However, the lowest grain yield (2.31 t ha^{-1}) was found in BRRI dhan53 with direct transplanting combination.

The physiological basis of the seedling hardening is still a topic of further study. Experiments considering different varieties and pre planting hardening of seedling and duration should be carried out to obtain a concrete recommendation.

REFERENCES

Ahmed, M. R., Rashid, M. A., Alam, M. S., Billah, K. A. and Jameel, F. (1997). Performance of eight transplant aman rice varieties under irrigated conditions. *Bangladesh Rice J.* **8**(1 &2): 43-44.

AIS (Agriculture Information Service). (2011). Krishi Dairy. Khamarbari, Farmgate, Dhaka-1215, Bangladesh.

Akbar, M. K. (2004). Response of hybrid and inbred rice varieties to different seedlings ages under system of rice intensification in transplant aman season. M. S. Thesis. Dept. of Agron. BAU, Mymensingh, Bangladesh.

Alauddin, M. H. (2004). Effect of methods of transplanting and seedlings per hill on the growth and yield of transplant aman rice cv. BRRI dhan39. M. S. Thesis. Dept. of Agron., BAU, Maymensingh, Bangladesh.

Al-Mamun, M. A., Shultana, R., Bhuiyan, M. K. A., Mridha, A. J. and Mazid, A. (2011). Economic weed management options in winter rice. *Pak. J. Weed Sci. Res.* **17**(4):323-331.

Ao, P. X., Li Z. G., Fan, D. M. and Gong, M. (2012). Involvement of antioxidant defense system in chill hardening-induced chilling tolerance in *Jatropha curcas* seedlings. *Acta Physiol Plant*. **35**: 153-160.

Ashrafuzzaman, M. (2006). Influence of tiller separation days on yield and yield attributes of inbred and hybrid rice. M.S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Austin, R. B., Longden, P. C. and Hutchinson, J. (1969). Some effects of "hardening" carrot seed. *Ann. Bot.* **33**: 883-895.

BBS (Bangladesh Bureau of Statistics). Estimates of Aman Rice, 2013-2014.

Bhatt, R. M. and Rao, N. K. S. (2005). Influence of pod load response of okra to water stress. *Indian J. Plant Physiol.* **10**: 54-59.

Bhuiyan, M. R., Rashid, M. M., Roy, D., Karmakar, B., Hossain, M. M. and Khan, M. A. I. (2011). Sound weed management option for sustainable crop production. *Bangladesh J. Weed Sci.* **1**(1):25-29.

BINA (Bangladesh Institute of Nuclear Agriculture). (1993). Annual Report for 1992- 1993. Bangladesh Inst. Nuclear Agric. P.O. Box No. 4. Mymensingh, Bangladesh. pp. 52-143.

Boses, S. R. and Huner, N. P. A. (1990). Effect of growth temperature and temperature shifts onspinach leaf morphology and photosynthesid. *Plant physiol.* **94**: 1830-1836.

BRRI (Bangladesh Rice Research Institute). (1985). Annual Report for 1982. BRRI Pub. No.79. Bangladesh Rice Res. Inst. Joydehpur, Gazipur, Bangladesh. p. 237.

BRRI (Bangladesh Rice Research Institute). (1985). Annual Report for 1983-1984. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. pp. 136-238.

BRRI (Bangladesh Rice Research Institute). (1991). Annual Report for 1988, Joydebpur, Gazipur, Bangladesh. pp. 40-42.

BRRI (Bangladesh Rice Research Institute). (1991a). Annual Report for 1988-1989. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. pp. 74-77.

BRRI (Bangladesh Rice Research Institute). (1991b). Annual Report for 1988-1989. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. p. 75.

BRRI (Bangladesh Rice Research Institute). (1991c). Annual Report for 1988-1989. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. p. 77.

BRRI (Bangladesh Rice Research Institute). (1996). Annual Report for 1994-1995. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. pp. 7-8.

Cantliffe, D. J., Elballa, M., Guedes, A., Odell, G. B., Perkins-Veazie, P., Schultheis, J. R., Seale, D. N., Shuler, K. D., Tanne, I. and Watkins, J. T. (1987). Improving stand establishment of direct seeded vegetables in Florida. *Proc. Fla. State Hort. Soc.* **100**: 213-216.

Castonguay, Y., Nadeau, P., Lechassuer, P. and Chauinard, L. (1995), Differential accumulation of carbohydrate in alfalfa cultivars of contrasting winter hardiness. *Crop Sci.* **35**: 50-516.

Chang, T. T. and Vergara, B. S. (1972). *Rice Breeding*, IRRI, Philippines. p. 727.

Chao, Y. Y. and Kao, C. H. (2010). Heat shock-induce ascorbic acid accumulation in leaves increases cadmium tolerance of rice (*Oryza sativa* L.) seedlings. *Plant Soil.* **336**: 39-48

Chao, Y. Y., Hsu, Y. T. and Kao, C. H. (2009). Involvement of glutathione and heat schok- and hydrogen peroxide-induced cadmium tolerance of rice (*Oryza sativa* L.) seedlings. *Plant Soil.* **318**: 37-45.

Chou, T. S., Chao, Y. Y. and Kao, C. H. (2012). Involvement of hydrogen peroxide in heat shock- and cadmium-induced expression of ascorbate peroxidase and glutathione reeducates in leaves of rice seedlings. *J. plant Physiol.* **169**(5): 478-486.

Cui, J., Kusutani, A., Toyota, M. and Asanuma, K. (2000). Studies on the varietal differences of harvest index in rice. *Japanese J. Crop Sci.* **69**(3): 357-358.

Debnath, A., Biswas, P. K., Sardar, M. S. A. and Rahman, A. (2012). Influence of mother and clonal tillers on yield and performance of inbred and hybrid *boro* rice. *Bangladesh Agron. J.* **15**(1): 1-7.

FAO (Food and Agriculture Organization). (2013). FAO Statistics. Internet Edition. http://faostat.fao.org/site/339/default.aspx. Accessed in October, 2013.

Farooq, M., Basra, S. M. A. and Ahmad, N. (2005). Rice seed priming. *Intl. Rice Res. Notes* **30**(2): 45-47.

Farooq, M., Basra, S. M. A., Ahmad, N. and Hafeez, K. (2005). Thermal hardening: A new seed vigor enhancement tool in rice. *J. Integ. Plant Biol.* **47**(2): 187-193.

Ferreira-Silva, S. L., Voigt, E. L., Silva, E. N., Maia, J. M., Fontenele, A. V. and Silveira, J. A. G. (2011). High temperature positively modulates oxidative protection in salt-stresses cashew plants. *Environ. Exp. Bot.* **74**: 162-170

Giuanta, F., Mortzo, R. and Deielda, M. (1993). Effect of drought on yield and yield components of durum wheat and triticale in Mediterranean environment. *Field Crops Res.* **33**: 399-409.

Gogoi, N. and Baruah, K. K. (1999). Effect of cold and chemical hardening on growth, yield and some biochemical character in 'boro' rice (*Oryza sativa*). *Indian J. Plant Physiol.* **4**: 179-184.

Gomasta, A. R., Quayyum, H. A., Molla, A. H. and Haque, M. Z. (1990). Storage of seedlings for transplant aman rice. *Bangladesh Rice J.* **1**(1): 55-63.

Haque, M. A. (1997). Effect of storage duration of uprooted seedlings under different conditions on the performance of BR 11 rice, M. S. Thesis. Dept. of Agron., Bangladesh Agricultural University, Mymensingh, Bangladesh. p. 37.

Hossain, S. M. A., Alam, A. B. M. and Khashem, M. A. (1991). Performance of different varieties of boro rice. In: Fact Searching and Intervention in two FSDP Sites. Activiies 1989-90. Farming syst. Res. and Devt. Prog. Bangladesh Agril. Univ. Mymensing, Bangladesh. pp. 150-154.

IRRI (International Rice Research Institute). (2013). Internet Edition. http://irri.org/our-impact/increase-food-security. Accessed in August, 2013.

Julfiquar, A. W., Virmani, S. S., Haque, M. M., Mazid, M. A. and Kamal, M. M. (2009). Hybrid rice in Bangladesh: opportunities and challenges. Rice research for food security and poverty allevation.Proc. Int. Rice Research Conference.

Kaykobad, S. M. A., Ahmed, M., Hoque, M. M. and Mannan, M. A. (2003). Effect of storage conditions and storage durations of uprooted rice seedlings on the yield and yield contributing characters of autumn rice. *J. Agric. Sci.* **36**(2): 91-96.

Kumar, A., Mishra, B. N. and Mishra, P. K. (2002). Effect of age of seedlings and plant density on growth and yield of hybrid rice. *Ann. Agric. Res.* **23**(3): 381-386.

Kumber, D. D. and Sonar, K.R. (1978). Grain yield and mineral composition of rice varieties grown under upland conditions. *Int. Rice Res. News.* **27**(2): 7-8.

Leenakumari, S., Mahadevappa, M., Vidyachandra, B. B. and Krishnamurthy, R. A. (1993). Performance of experimental rice hybrids in Bangalore, Karnataka, India. *Intl. Rice Res. Notes.* **18**(1): 16.

Main, M. A., Biswas, P. K. and Ali, M. H. (2007). Influence of planting material and planting methods on yield and yield attributes of inbred and hybrid rice. *J. Sher-e-Bangla Agric. Univ.* **1**(1): 72-79.

Miller, T. L. (1978). Rice performance trails, sixteen varieties tested at Datta Branch Station. *MAFFS Res. Highlight.* **41**(2): 6.

Mondal, M. R. I. and Choudhury, D. A. (2014). Agronomic visions for sustainable food Security. Keynote paper presented at the 13th Biennial Conference of the Bangladesh Society of Agronomy. pp. 26-29.

Nascimento, W. M. (2003). Muskmelon seed germination and seedling development in response to seed priming. *Sci. Agric.* **60**: 71-75.

Obaidullah, M. (2007). Influence of clonal tiller age on growth and yield of aman rice varieties. M. S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Om, H., Katal, S. K., Dhiman, S. D. and Sheoran, O. P. (1999). Physiological parameters and grain yield as influence by time of transplanting and rice (*Oryza sativa*) hybrids. *Indian J. Agron.* **44**(4): 696-700.

Rajshekar, C. B. and Lafta, A. (1996). Cell-well changes and cell tension in response to cold acclimation and exogenous abscisic acid in leaves and cell culture. *Plant Physiol.* **111**: 605-611.

Reza, M. S. U. A., Karim, S. M. R. and Begum, M. (2010). Effect of nitrogen doses on the weed infestation and yield of boro rice. *Bangladesh J. Weed Sci.* **1**(1): 7-13.

Sarkar, R. K., Sanjukta, D. and Das, S. (2003). Yield of rainfed lowland rice with medium water depth under anaerobic direct seeding and transplanting. *Trop. Sci.* **43**(4): 192-198.

Tae, T. H., Hirano, M., Iwamoto, S., Kuroda, E. and Murata, T. (1998). Effect on topdressing and planting density on the number of spikelets and yield of rice cultivated with nitrogen-free basal dressing. *Plant Prod. Sci.* **1**(3): 191-198.

Tiryaki, I. and Buyukcingil, Y. (2009). Seed priming combined with plant hormones: influence on germination and seedling emergence of sorghum at low temperature. *Seed Sci. Technol.* **37**: 303-315.

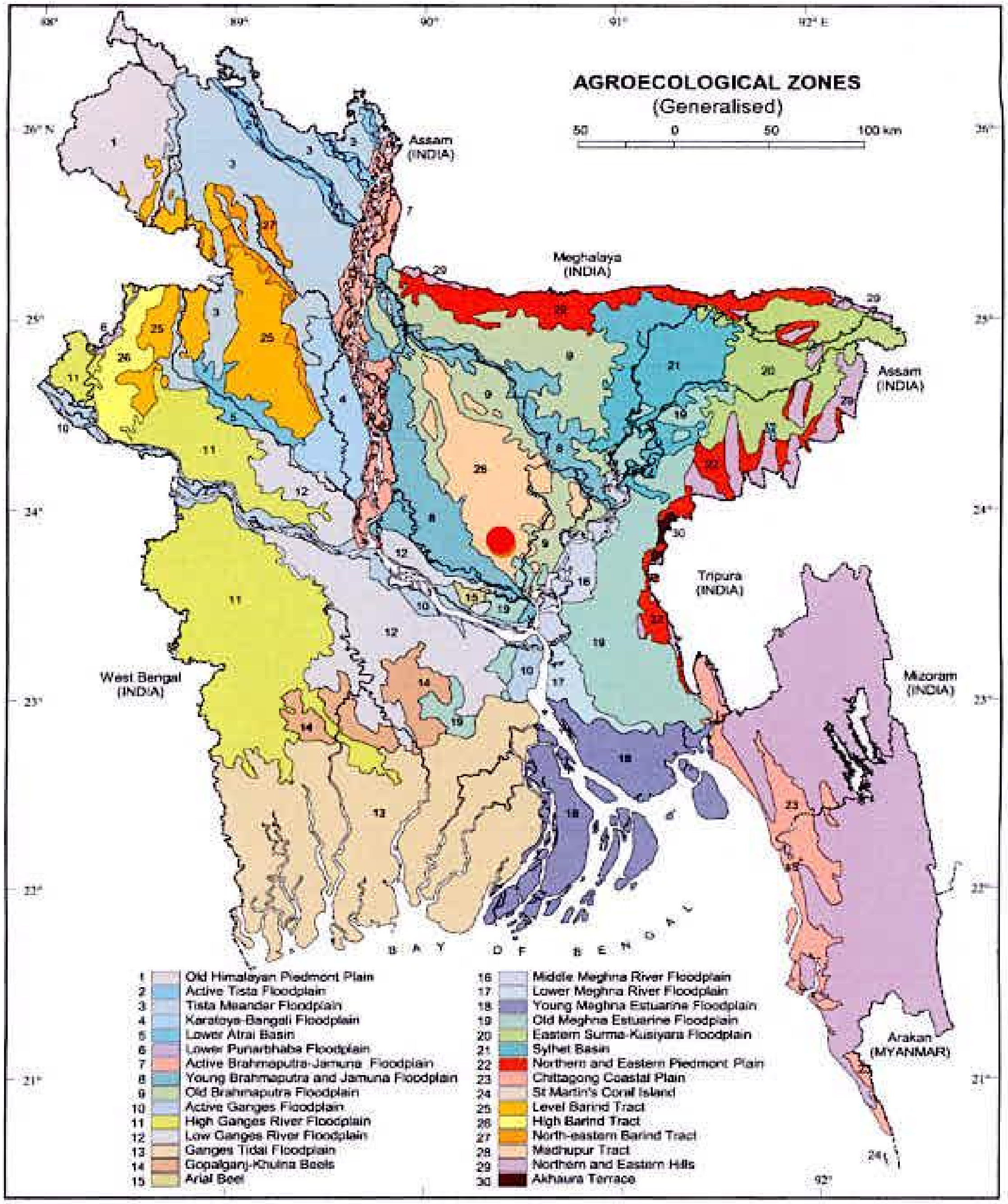
Uemura, M. and Peter, L, Steponkus. (1997). Effect of cold acclimation on the lipid composition of inner and outer membrane on the chloroplast envelope isolated from rye leaves. *Plant Physiol.* **144**: 1493-1500.

Wen Xiong, L., Yiyuan, L. and Ting C. W. (1996). The heterotic effects on dry matter production and grain yield formation in hybrid rice. *J. Fujian Agric. Uni.* **25**(23): 260-265.

Zhang, S., Hu J., Zhang, Y., Xie X. J. and Knapp, A. (2007). Seed priming with brassinolide improves lucerne (*Medicago sativa* L.) seed germination and seedling growth in relation to physiological changes under salinity stress. *Aust. J. Agril. Res.* **58**: 811-815.

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Characteristics	Value
Particle size analysis	
%Sand	27
%Silt	43
%Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI (Soil Resources Development Institute), Farmgate, Dhaka

Appendix III Monthly average air temperature, relative humidity, total rainfall rate of the experimental site during the period from August to November, 2013

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
August	31.02	15.27	74.41	5.1
September	31.46	14.82	73.20	6.3
October	30.18	14.85	67.82	4.2
November	28.10	6.88	58.18	1.56

Source: SAU Meteorological Yard , Sher-e-Bangla Nagar, Dhaka-1207.

Plate 1. Seedling at seedbed

Plate 2. Plot view of my experimental field

Plate 3. Harvesting stage of BRRI dhan53

Plate 4. Harvesting stage of Pajam variety

Plate 5. Measuring of Leaf Area Index (length)

Plate 6. Measuring of Leaf Area Index (Breadth)