Grain and Seed Quality of Manawthukha Rice (*Oryza sativa* L.) as Affected by Different Storage Containers and Storage Durations

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Abstract

To evaluate the grain and seed quality of Manawthukha rice variety as affected by different storage containers and storage durations and to identify the proper storage container and storage duration for quality of Manawthukha rice variety, experiments were carried out at Laboratory of the Department of Agronomy, Yezin Agricultural University from May 2016 to May 2017 for summer and monsoon rice. In each experiment, 3 x 3 factorial experiment was laid out in Randomized Complete Block (RCB) design with four replications. Factor A was assigned with three types of storage containers: air tight tin bin, bamboo basket and woven plastic bag, and three storage durations: no storage, two months storage, and four months storage were laid out as factor B. Seed samples were stored at ambient conditions. In both storage seasons, head rice yield and 1000 grain weight were significantly different. Milling yield, germination percentage, germination index and seedling vigor index were highly differed by the effect of storage duration except the milling yield in summer rice storage. Grain and seed quality were significantly influenced mostly due to the effect of storage duration rather than storage container for storage period. Air tight tin bin maintained grain moisture relatively stable during the storage. Four months storage with air tight tin bin gave the highest head rice yield in seed quality. Woven plastic bag gave the highest seedling vigor index in seed quality.

Key words: Manawthukha rice, storage container, duration, grain quality, seed quality

Introduction

Rice is the world's single most important foodstuffs as well as an important and nutritionally vital food commodity that feeds more than half of the world's population (Deepak and shukla 2011). In Myanmar, rice is important in national and international trade with political and social implications. Manawthukha variety was sown 1.125 million hectares during 2015-2016 monsoon season and 94.1 thousand hectares in summer season (MOALI 2016).

Seed is one of the essential inputs of agriculture determining crop productivity and quality seed may increase rice yield by 15-20% as well as improve grain quality and market acceptability (Fakir 2004). In Myanmar, most of rice farmers use their own seed from year to year and readily distributed through informal farmer-to-farmer mechanisms (Glenn et al. 2013).

Storage is essential for food security or as a product bank for exchange into cash when required (Mejia 2003). Rice is normally stored unhulled or paddy rather than as milled rice for both consumption and seed, as the husk protects against insects and prevents quality deterioration. Grain and seed is stored on-farm in jute bags, woven plastic bags, traditional storage granaries, baskets, drums, and other containers (Glenn et al. 2013).

Storage duration is another factor, which affects seed and grain quality. Rice is stored several days to several weeks and also several years depend on the producers' and researchers' objectives (Zhou et al. 2001; Ali et al. 2005; Sultana et al. 2016).

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Aging or storing rough rice for 3-4 months after harvest also affects on grain quality (Villareal et al. 1976). Proper storage conditions are crucial in maintaining quality and the value of stored rice. Therefore, this research experiment was carried out to point out the proper storage conditions for Manawthukha rice variety.

Materials and Methods

Experiments were carried out at laboratory of the Department of Agronomy, at Yezin Agricultural University, Nay Pyi Taw from May to September 2016 for summer rice storage and from December 2016 to May 2017 for monsoon rice storage. Manawthukha rice variety was used as the tested variety. Rice sample was collected from local farmer in Mandalay Township, Mandalay Region. The moisture contents of rice samples were set to around 12.5 ± 0.2% by natural sun drying method. Six kilograms of samples were put in each type of container and stored at ambient condition. Experiments were subjected to a 3x3 factorial in Randomized Complete Block (RCB) design with four replications. Storage container was assigned as factor A comprising of three types: air tight tin bin, bamboo basket and woven plastic bag, whereas storage duration was considered as factor B comprising of three levels: no storage, two months and four months storage. Grain and seed quality parameters were determined by the following methods.

1000 grain weight

One thousand of whole grains from each replicate were randomly taken and measured in gram by using electronic digital balance.

Milling yield and head rice yield

One kilogram of paddy sample was milled by using a laboratory rice mill and weight of milled rice was recorded. Then head rice including whole milled rice and those that were at least three quarters in length were separated by hand. Milling yield and head rice yield were calculated by the following formulae.

$$\text{Milling yield (\%)} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of paddy sample (g)}} \times 100$$

(IRRI 2013)

$$\text{Head rice yield (\%)} = \frac{\text{Weight of head rice (g)}}{\text{Weight of paddy sample (g)}} \times 100$$

(IRRI 2013)

Moisture content (wet basic)

Two grams of ground sample was taken from each replicate and dry it in the oven at 130°C for 1 hour (AACC 1999). Moisture content of samples was calculated by the following formula.

$$\text{Moisture content (\%)} = \frac{\text{Initial weight (g)} - \text{final weight (g)}}{\text{Initial weight (g)}} \times 100$$

(IRRI 2013)

Germination percentage and germination index

One hundred seeds were randomly selected from each replicate of seed samples. These were placed on absorbent material inside the Petri dish and checked that absorbent material remain moist. The germination and seedling growth were daily observed for 7 days and 10 days to determine germination index and germination percentage, respectively. The number of germinated seeds were recorded, and germination percentage and germination index were calculated by the following formulae.

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds on tray}} \times 100$$

(IRRI 2013)

$$\text{Germination index} = \frac{N_1}{D_1} + \frac{N_2}{D_2} + \ldots + \frac{N_n}{D_n}$$

(IRRI 2013)

Where:

$N_1, N_2, \ldots, N_n$: Number of emerged seedlings on 1^{st}, 2^{nd} and n^{th} day after seeding

$D_1, D_2, \ldots, D_n$: Number of days after seeding (1^{st} to 7^{th} days).

Seedling vigor index

At the end of germination test (10 days), the seedling length was measured from 10 normal seedlings of each replication. It was measured from shoot tip to root tip and seedling vigor index was calculated by using the following formula.

$$\text{Seedling vigor index} = \text{Germination (\%)} \times \text{Seedling length (mm)}$$

(ISTA 1996)

Amylose content

Amylose content was determined by using the simplified iodine colorimetric procedure by the method of Juliano (1971). Twenty grains were selected and ground in the UDY Cyclone Mill. Samples were categorized into low, intermediate and high based on the standard graph method of Williams et al. (1985). When the amylose content of sample is 0-7%, that sample can be classified as waxy, when amylose content is 8-20%, classified as low, when 21-25%, classified as intermediate and > 25%, classified as high.

Gelatinization temperature

Gelatinization temperature was measured using alkali-spreading value. The alkali digestibility test was employed. Grains were soaked in 1.7% KOH and incubated in a 30°C oven for 23 hours by the method of Juliano (1971). Measurement ranges were based on the following:

Category	Temp ranges (°C)	Alkali Spread
Low	55-69	6-7
Intermediate	70-74	4-5
High	75-79	2-3

Gel consistency (GC)

Gel consistency was determined according to the method of Cagampang et al. (1973). For each sample, 100 mg of rice powder flour was placed into a glass test tubes, 0.2 ml of thymol blue in ethanol solution was added, followed by shaking with addition of 2.0 ml of 0.2N KOH. The mixture was then boiled in a water bath followed by cooling in ice cold water. The tubes were then kept horizontally on a millimeter paper and the length of the gel was measured from the bottom of the test tube after 45 min. Measurement ranges and category were, when sample gel length is 61-100 mm, that sample can be categorized as soft, when gel length is 41-60 mm, categorized as medium and 26-40 mm gel length, categorized as hard.

Elongation ratio

Using a photographic enlarger 25 whole milled kernel's lengths were measured. These measured kernels were taken into a wire net and immersed in distilled water for 30 minutes. Then the net containing 25 rice kernels were placed in boiling water for 10 minutes. Then they was taken out and cooled to room temperature. The cooked kernels were transferred into properly labeled Petri dishes lined with Whatman No.1 filter paper. The kernels were allowed to dry at room temperature. The lengths of cooked kernels were measured using the photographic enlarger. The average lengths of raw and cooked kernels were calculated and the ratio of cooked to raw kernel was given as result.

Statistical Analysis

The data were subjected to analysis of variance by using the Statistix (version 8.0) software. Mean data of the tested treatments were compared by the Least Significant Difference (LSD) at 5% level. Correlation analysis was also performed by the method of Gomez and Gomez (1984).

Results and Discussions

Grain quality parameters in summer and monsoon rice storage

The mean values of grain quality as affected by different storage conditions in summer and monsoon rice storage are shown in Table 1.

1000 grain weight

Thousand grain weights of stored rice were different among three types of storage containers at 5% level in summer and at 1% level in monsoon rice storage. Maximum 1000 grain weight (18.28 g) was observed in summer rice storage and (20.33 g) in monsoon rice storage from air tight tin bin. The mean 1000 grain weights in bamboo basket (18.05 g) and woven plastic bag (18.18 g) in summer, and (19.95 g) and (19.92 g) in monsoon rice storage were not statistically different. Moreover, thousand grain weight was significantly varied among the storage durations ($Pr < 0.0001$) in both storage seasons. In summer rice storage, thousand grain weight increased with storage durations, however, it decreased in monsoon rice storage. Chakraverty et al. (2003) described that rice grains are hygroscopic and gain or lose water depending on the water vapor present in them and in ambient air to attain equilibrium.

Milling yield

In both seasons, the milling yield was not significantly different among all the treatments of dif-

Table 1. Mean effects of storage containers and storages duration on grain quality of Manawthukha rice variety in summer and monsoon rice storage

	Summer rice storage			Monsoon rice storage		
Treatments	**1000 grain weight (g)**	**Milling yield (%)**	**Head rice yield (%)**	**1000 grain weight (g)**	**Milling yield (%)**	**Head rice yield (%)**
Container						
Air tight tin bin	18.28 a	60.91	39.62 b	19.92 b	55.82 a	37.59 a
Bamboo basket	18.05 b	61.00	42.81 a	20.33 a	52.99 a	34.57 b
Woven plastic bag	18.18 ab	60.45	37.61 c	19.95 b	55.45 ab	36.08 ab
LSD $_{0.05}$	**0.16**	**2.47**	**1.89**	**0.20**	**2.63**	**2.07**
Duration (month)						
No storage	17.92 b	61.15	41.61 a	20.56 a	58.60 a	34.63 b
Two	18.27 a	60.45	40.42 a	20.04 b	56.52 a	38.94 a
Four	18.32 a	59.96	38.02 b	19.60 c	49.14 b	34.67 b
LSD $_{0.05}$	**0.16**	**2.47**	**1.89**	**0.20**	**2.63**	**2.07**
Pr ≥ F						
Container	0.02	0.89	< 0.0001	0.0002	0.07	0.02
Duration	< 0.0001	0.50	0.002	< 0.0001	< 0.0001	0.0002
Container x Duration	0.17	0.93	0.007	0.04	0.04	0.13
CV %	**1.01**	**4.83**	**5.61**	**1.16**	**5.71**	**6.81**

In each column, means having a common letter are not significantly different at 5% level of LSD

ferent storage containers and different storage durations. These results might be due to insufficient storage duration. The maximum milling yield (61.00%) was obtained from bamboo basket in summer rice storage but woven plastic bag (55.82%) in monsoon rice storage. Nevertheless, milling yields were significantly different among storage durations (Pr < 0.0001). Milling yield decreased with storage durations. This may be due to the improvement in dryness of rice grains on storage particularly in non-air tight container. Similarl finding was reported by Rosario et al. (2017). The maximum milling yield was resulted from no storage which was not significantly different from that of two months storage. The lowest milling yield was resulted from four months storage.

Head rice yield

The results showed significant differences in head rice yield among storage containers at 1% level in summer rice storage but at 5% level in monsoon rice storage. This result might be due to different moisture equilibrium of seeds stored in different types of containers. Among the storage containers, bamboo basket gave the highest head rice yield (42.81%) in summer rice storage and woven plastic bag (37.59%) in monsoon rice storage. Moreover, head rice yields were significantly different among storage durations in both storage seasons. Ankit (2014) stated that head rice yield and cooking properties were also affected ($p < 0.05$) by storage duration. The maximum head rice yield was resulted from no storage (41.61%) in summer rice storage but two months storage (38.94%) in monsoon rice storage.

Seed quality parameters

The mean effects of seed quality as different storage containers and storage durations are shown in Table 2.

Moisture content

The average moisture content of rice storage was (12.5± 0.2%) in both storage samples before storage. In both storage seasons, the moisture content of stored rice significantly varied among types of storage containers (Pr < 0.0001). Among the storage containers, air tight tin bin could maintain their grain moisture content relatively stable as no storage. The other two containers were not air tight and therefore moisture fluctuation may be happened according to their equilibrium along storage. There was also significantly different in moisture content with storage durations (Pr < 0.0001).

In summer rice storage, grain moisture content decreased after two months storage compared to no storage, however, increased at the end of four months because storage durations were synchronized with wet season. Therefore moisture absorption of stored rice was occurred to reach their equilibrium. In monsoon rice storage, grain moisture content decreased after two months storage as well as after four months storage than no storage due to this storage synchronized during dry season and also storage containers were kept in ambient conditions. Dhaliwal et al. (1991) reported that the moisture content of paddy increased in all samples stored in no air tight bag (gunny bags) under ambient conditions with the onset of the monsoon. However, there was decreased sharply within a month and the moisture decreased further up to six months of storage, probably due to low temperature and dry weather.

Germination percentage

In both storage seasons, germination percentage was not affected by types of storage containers (Pr = 0.38). In summer rice storage, air tight tin bin gave the maximum germination percentage (96.08%) followed by woven plastic bag (96.00%) and bamboo basket (95.25%). Numerically, bamboo basket gave the maximum germination percentage (70.25%) followed by woven plastic bag (69.58%) and air tight tin (68.75%) in monsoon storage. This result might be due to good and stable germinability of Manawthukha variety even in the different containers. On the other hand, significant differences of germination percentage were found in storage durations (Pr < 0.0001) in both storage seasons. Chowdhury et al. (2014) found that not only storage containers but also storage period had a significant effect on the germination percentage of rice seed after 120 days of storage period.

In both storage seasons, germination percentage was significantly lower before storage compared to stored rice. However, germination percentage was significantly higher at two months and four months after storage. Low germination percentage of fresh rice may be mainly due to seed dormancy, especially in Manawthukha rice variety. However, storage could break dormancy, and therefore germination percentage was increased after each storage duration.

Germination index

Types of storage containers did not significantly influence on germination index in both storage seasons. The maximum germination index (28.52) was found in air tight tin bin followed by woven plastic bag (28.5) and bamboo basket (28.07) in summer rice storage. In monsoon rice storage, the maximum germination index (18.93) was obtained from bamboo basket followed by woven plastic bag (18.63) and air tight tin bin (17.54). In both storage seasons, effect of storage duration on germination index significantly differed at 1% level. The lowest germination index (26.93) was found from fresh rice; however, there were obviously increased after two months and four months storage. Variation in germination index was regarded mainly as the consequence of variation in germination percentage in all tested treatments.

Seedling vigor index

In both storage seasons, seedling vigor index was not significantly different by types of storage containers (Pr = 0.65). This might be due to good viability of Manawthukha variety even in different storage containers in the different seasons. The maximum seedling vigor index (11979) in summer,

Table 2 Means effects of storage containers and storage durations on seed quality of Manawthukha rice variety in summer and monsoon rice storage

Treatments	Summer rice storage				Monsoon rice storage			
	Moisture Content (%)	Germination Percentage (%)	Germination index	Seedling vigor index	Moisture Content (%)	Germination Percentage (%)	Germination index	Seedling vigor index
Container								
Air tight tin bin	12.51 c	96.08	28.52	11680	12.37 a	68.75 b	17.54	7712.80 b
Bamboo basket	12.74 b	95.25	28.07	11771	10.85 c	70.25 a	18.93	8039.10 ab
Woven plastic bag	13.03 a	96.00	28.50	11979	11.14 b	69.58 ab	18.63	8207.40 a
LSD $_{0.05}$	**0.14**	**1.34**	**1.21**	**678.77**	**0.14**	**1.42**	**1.40**	**472.46**
Duration (month)								
No storage	12.69 b	90.50 c	26.93 b	10088 c	12.46 a	16.50 b	2.80 c	1417.00 c
Two	12.01 c	99.58 a	28.82 a	12260 b	11.17 b	95.75 a	18.74 b	10467.00 b
Four	13.57 a	97.25 b	29.33 a	13082 a	10.73 c	96.33 a	33.55 a	12075.00 a
LSD $_{0.05}$	**0.14**	**1.34**	**1.21**	**678.77**	**0.14**	**1.42**	**1.40**	**472.46**
Pr ≥ F								
Container	< 0.0001	0.38	0.69	0.65	< 0.0001	0.11	0.12	0.11
Duration	< 0.0001	< 0.0001	0.001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Container x Duration	< 0.0001	0.63	0.31	0.97	< 0.0001	0.44	0.50	0.45
CV %	**1.25**	**1.66**	**5.07**	**6.82**	**1.41**	**2.43**	**9.06**	**7.02**

and (8207.40) in monsoon rice storage were found in woven plastic bag followed by bamboo basket (11771) and air tight tin bin (11680) in summer. The highly significant differences were found in seedling vigor index with different storage durations ($Pr < 0.0001$). The highest seedling vigor index was obtained from four months storage followed by two months storage but the minimum value was obtained from no storage. Seedling vigor index of rice at three storage durations were significantly different from each other. However, Rosario et al. (2017) reported that seedling vigor index was significantly different in the different storage materials for fourth month of storage.

Physicochemical properties

Amylose content

The mean amylose content as affected by different storage conditions in summer and monsoon rice storage are shown in Figure 1. The mean amylose content of fresh rice was found about 31% that indicating high level of amylose content (Williams et al. 1985). In both storage seasons, amylose contents were slightly increased with storage durations almost in all types of storage containers. Increasing rate was higher in four months storage than in two months storage. Zhou et al. (2001) mentioned that the alpha-amylase and beta-amylase activities of rough rice samples decreased significantly during storage and unwell break amylose content is accumulated in stored rice. Therefore, amylose content of stored rice is usually higher than that of fresh rice. In summer rice storage, maximum amylose content of stored rice was resulted from bamboo baskets (32.2%) in two months, (34.80%) in four months storage, however, in monsoon rice storage, there was resulted from woven plastic bag (32.3%) in summer,and (32.5%) in monsoon rice storage.

Gel consistency

Gel consistency as affected by different storage containers and storage durations is showed in Figure 2. The mean gel consistency of rice before storage was found to fall in the category of "intermediate" in both storage seasons (Cagampang et al. 1973). However, gel length decreased to "hard" level during storage. Gel consistency obviously decreased in two months storage. Because starch of fresh rice is formed in a solution state, but it has been changed into granules during storage. Therefore, rice flour from freshly harvested rice is generally softer and stickier than that from aged rice (Kanlayakrit and Maweang 2013). Regardless of gel consistency of fresh rice (46 mm), the maximum gel consistency (31.5 mm) was observed from air tight tin bin in two months storage and woven plastic bag in four months storage (30.0 mm). Reversible result was observed in monsoon rice storage, the maximum gel consistency (31.5 mm) was observed from woven plastic bag in two months storage and air tight tin bin in four months storage (29.0 mm).

Gelatinization temperature

Gelatinization temperature as affected by different storage containers and storage durations are presented in Figure 3 for both storage seasons. In both storage seasons, gelatinization temperature of Manawthukha rice belonged to high/intermediate level (74-75°C) (Juliano 1971) at fresh rice stage. Gelatinization temperature distinctly increased after two months storage in all storage containers. There were similar gelatinization temperatures among types of storage containers. In addition, gelatinization temperature was remained unchanged after four months storage in all types of storage containers as in two months storage. Similar finding was reported by Wattinee and Charoenrein (2014). Hull (1955) reported that under normal storage conditions grains exhibit continuous physicochemical changes due to the physiological activities of the germ and endosperm, and these affect cooking properties and nutritive value.

Elongation ratio

The mean elongation ratio of rice as affected by different storage containers and storage durations is shown in Figure 4 for both seasons. In summer rice storage, elongation ratio obviously increased with storage duration. This result indicated that the elongation ratio of cooked rice increases during aging process as a result of changes in rice grains leading to more water absorption during cooking, resulted in larger volume of cooked rice (Chrastil 1994). Elongation ratio (1.8) was remained stable in two months storage among the storage containers, however, the maximum elongation ratio (1.9) was ob-

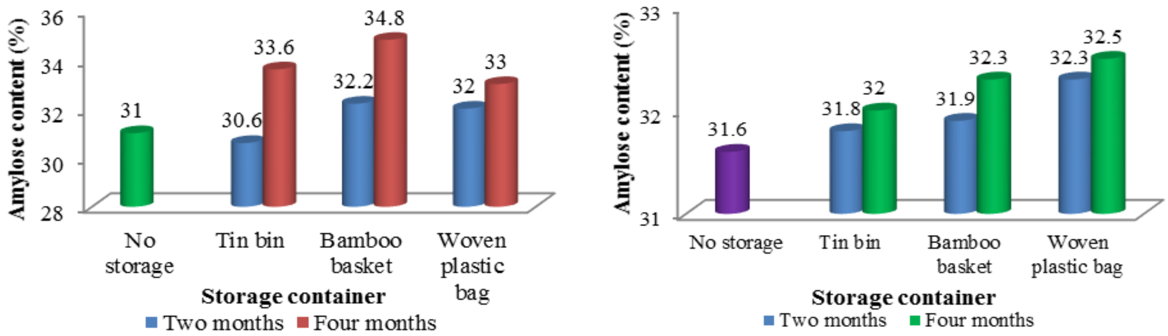

Figure 1. Mean values of amylose content as affected by storage containers and storage durations (a) in summer rice storage and (b) in monsoon rice storage

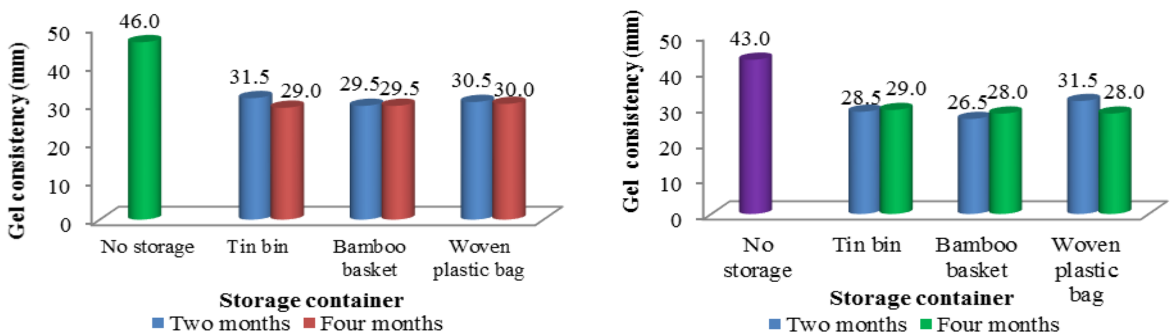

Figure 2. Mean values of gel consistency as affected by storage containers and storage durations (a) in summer rice storage and (b) in monsoon rice storage

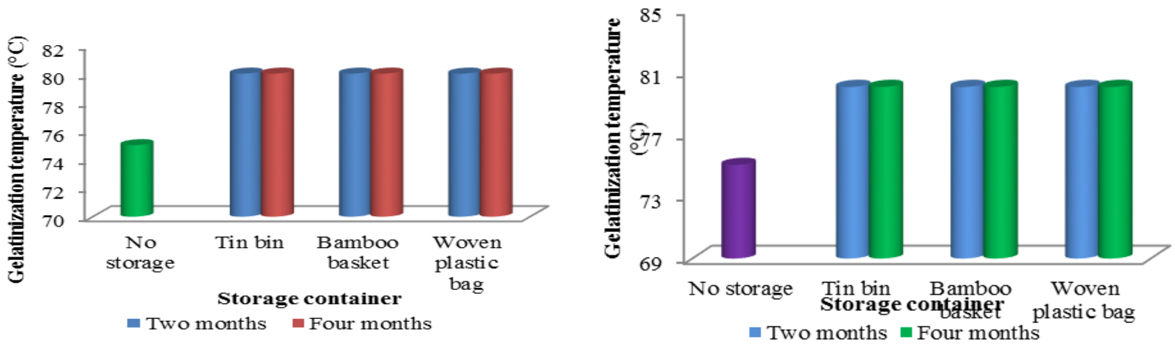

Figure 3. Mean values of gelatinization temperature as affected by storage containers and storage durations (a) in summer rice storage and (b) in monsoon rice storage

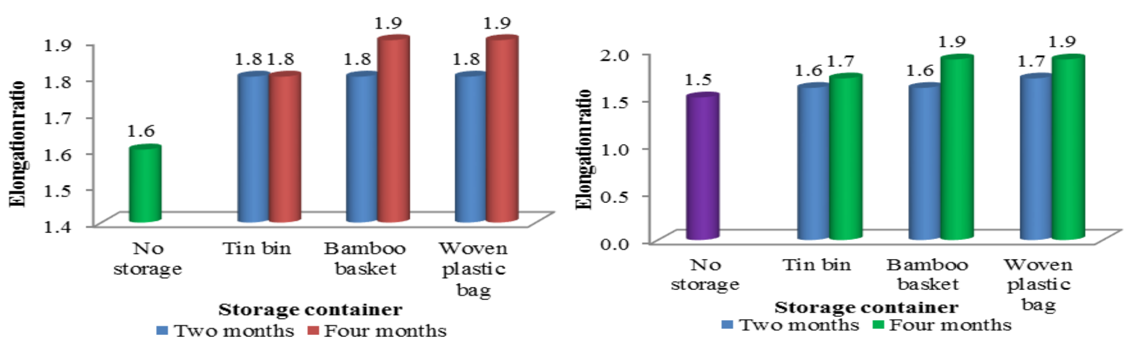

Figure 4. Mean values of elongation ratio as affected by storage containers and storage durations (a) in summer rice storage and (b) in monsoon rice storage

served from bamboo basket and woven plastic bag in four months storage respectively. In monsoon rice storage, bamboo basket and woven plastic bag also gave maximum elongation ratios (1.9) in four months storage duration.

Conclusion

Head rice yield and 1000 grain weight were significantly different as a result of significant variation in moisture content of stored seed by the responses to types of storage container and storage duration. Milling yield, germination percentage, germination index and seedling vigor index were highly differed by the effect of storage duration except the milling yield in summer rice storage. In physicochemical properties, amylose content, gelatinization temperature and elongation ratio were increased, and gel consistency was decreased with storage in all treatments. However, the rates of changes were higher in four months storage than in two months storage, with the exception of gelatinization temperature and gel consistency, which were not changed due to difference in storage duration. For grain quality, rice should be stored in air tight tin bin in order to get the highest head rice yield especially in summer rice storage during four months. For seed quality, woven plastic bag should be used to ensure the higher seedling vigor index in both summer and monsoon rice storage for four months. Further study may be needed to investigate the long-term effect of this storage containers and storage durations.

References

AACC International (the American Association of Cereal Chemists International) 1999. Approved methods of analysis, (11th edn.), AACC International, St. Paul, MN, U.S.A.

Ali, Z., R. Mohammad, T. Tajattodi and Kobra. 2005. Study on the effects of husking degree on percentage of rice breakage in different varieties, Rice Research Institute of Tran, Rasht, Iran. pp. 12-16.

Ankit, K. 2014. Studies on storability of brown rice, Department of Post Harvest Process and Food Engineering, College of Agricultural Engineering, Jabalpur, India.

Cagampang, G. B., C. M. Perez and B. O. Juliano. 1973. A gel consistency test for eating quality of rice. Journal of the Science of Food and Agriculture, 24: 1589-1594.

Chakraverty, A., A. S. Mujumdar, G. S. V. Raghavan and H. S. Ramaswamy. (eds.). 2003. Handbook of postharvest technology: cereals, fruits, vegetables, tea, and spices, Marcel Dekker Inc., Newyork Beasel. 912p.

Chowdhury, S., M. A. H. Chowdhury, S. Bhattacherjee and K. Ghosh. 2014. Quality assessment of rice seed using different storage techniques, Journal of Bangladesh Agricultural University, 12(2): 297-305.

Chrastil, J. 1994. Effect of storage on the physicochemical properties and quality factors of rice. In E. W. Marshall and I. W. James (eds.), Marcel Dekker Inc., Rice Science and Technology (1st edn.). Louisiana, U.S.A. pp. 49-75.

Deepak, K. and K. Shukla. 2011. National value of rice and their importance, India Farmers' Digest, 44(1).

Dhaliwal, Y. S., K. S. Sekhon and H. P. S. Nagi. 1991. Enzymatic activities and rheological properties of stored rice, Americal Association of Cereal Chemists, Inc., Cereal Chemistry, 68 (1): 18-21.

Fakir, G. A. 2004. A monograph on seed health and quality of farmer-saved rice seed in Bangladesh, Rice seed health improvement subproject, PETRRA, IRRI, Banani, Dhaka. 53p.

Glenn, D., K. Baroang and T. M. Sandar. 2013. Rice productivity improvement in Myanmar, Background paper, no.2.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedures for agricultural research (2nd edn.), John Wiley and Sons, Inc., U.S.A. 680p.

Hasanuzzaman, M. 2015. Seed quality, Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh.

Hull, D. W. 1955. Problems of food storage in tropical territories. Annals of Applied Biology, 42 (1): 85-97.

IRRI (International Rice Research Institute). 2013. Seed quality training manual, Rice knowledge bank, Agricultural engineering unit, International Rice Research Institute, P .O. Box 933, Manila, Philippines. 23p.

ISTA (International Seed Testing Association). 1996. International rules for seed testing, Seed Science and Technology, 4: 3-177.

Juliano, B. O. 1971. A samplified assay for milled rice amylose cereal, Science Today, 16: 334-360.

Kanlayakrit, W. and M. Maweang. 2013. Postharvest of paddy and milled rice affected physicochemical properties using different storage conditions, International Food Research Journal, 20(3): 1359-1366.

Mejia, D. J. 2003. An overview of rice post-harvest technology: use of small metallic silos for minimizing losses, Proceedings of the 20th session of the international rice commission, Bangkok, Thailand, 23-26 July 2002, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

MOALI (Ministry of Agriculture, Livestock and Irrigation) 2016. Myanmar agriculture sector in brief, Ministry of Agriculture, Livestock and Irrigation, Myanmar.

Rosario, del M. R., C. R. Lucero, R. L. Sollestre and R. J. G. Villaluz. 2017. Development and evaluation of a charcoal-insulated paddy storage bin, College of engineering, Laguna State Polytechnic University, Philippines, American Journal of Engineering Research (AJER), 6(1): 128-133.

Sultana, N., Md. Y. Ali, Md. S. Jahan and S. Yasmin. 2016. Effect of storage duration and storage devices on seed quality of Boro rice variety BRRI dhan47, Journal of Plant Pathology and Microbiology, 8(1): 2-6.

Villareal, R. M., A. P. Resurreccion, L. B. Suzuki and B. O. Julino. 1976. Changes in physicochemical properties of rice during storage, Starke, 28: 88-94.

Wattinee, K. and S. Charoenrein. 2014. Effect of rice ageing and freeze-thaw cycle on textural properties of cooked rice (*Oryza sativa* L.) cv. Khao Dawk Mali 105, Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok, Thailand, International Journal of Food Science and Technology, 49(10): 2283-2289.

Williams, V. R., W. T. Wu, H. Y. Tsai and H. G. Bates. 1985. Varietal differences in amylose content of rice starch, J. Agri. Food Chem., 6: 47-48.

Zhou, Z., K. Robards, S. Helliwell and C. Blanchard. 2001. Ageing of stored rice: Changes in chemical and physical attributes, Journal of Cereal Science, 33: 1-15.