Investigation on the Effect of Various Storage Conditions on the Quality of Two Upland Varieties

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***Abstract*—Upland rice (*Oryza sativa*) is an important staple crop especially for farmers in rural poverty areas. Low temperature and low humidity is an ideal condition for storage of the seed; however, most upland rice growers have low income resulting in an impossible way to store seeds in ideal conditions. In this study, we monitored seed quality from seeds that were stored in four storage conditions for fourteen months. Seeds from both varieties were able to maintain their quality in all storage conditions until seven months after harvested. This suggests that it is acceptable to store seeds at room temperature if the seeds will be used before seven months after they were harvested. On the other hand, seeds that were stored in room temperature with silica gel, 4 ℃ and 4 ℃ with silica gel were able to maintain their quality (86.70, 90.00% viability and 67.50, 69.25% germination) until twelve months after they were harvested. Interestingly, no significant difference found in 'Knaow Jhaow Doi' seeds that were stored at those conditions at twelve months after harvested. Therefore, low humidity without controlling temperature can be an alternative way to store upland rice. Because this storage method is easy to handle, and is suitable for upland rice growers.**

***Index Terms*—upland rice, seed quality, storage condition, seed germination test, viability test**

I. Introduction

Rice (*Oryza sativa*) is the second highest worldwide production of cereal grains. The majority of the world rice productions are irrigated rice, and about 4% is upland rice [1]. Upland rice is known for its rich source of biodiversity, complexity, and their ability to grow in diverse climate conditions. Irrigated rice requires irrigation systems and well-drained soil conditions in field areas; however upland rice can grow in varies climatic conditions such as humid to sub-humid, flat fields to sloped fields, very low fertile soils to highly infertile soils; moreover, their able to withstand prolonged drought. Upland rice is accountable for majority of food in rural poverty areas including Asia, Africa, and Latin America [1].

Although upland rice is able to grow in various field conditions; however, its production is very low. [2], reported that productivity of upland rice is only 59% when compared with paddy rice. There are several factors that could limit the yield of upland rice such as weeds, blast disease, brown spots, and low seed quality. Amongst those constraints, low seed quality is considered as a major barrier in upland rice production [1], [3]. In order to produce a high quality seed, proper maintenance of genetic purity, good growing conditions, proper timing, method of harvesting, and appropriate seed storage and seed distribution systems are required [4]. As for upland rice, farmers have been using their own seeds from previous harvests that were stored in improper storage conditions which resulted in low seed quality [3]; therefore, appropriate post harvest technique including drying the seed and storage conditions become very important for increasing the yield of upland rice. Major factors that have big impacts on seed quality after storage are moisture and temperature [5]-[9]. However, storage of seeds in a low temperature environment is a major obstruction especially for most of upland rice cultivation in rural poverty areas. In this study we will be investigating the quality of seeds that were stored in various conditions. The results from this study will provide imperative information for proper seed storage conditions to maintain for upland rice growers.

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II. Methodology

A. Plant Materias

The seeds of two upland rice (*Oryza sativa*) varieties 'Mae Suai' and 'Knaow Jhaow Doi' from Northern area in Thailand were used in this study. Seeds were obtained from upland rice farmers in Mae Sai and Phan district, Chiang Rai province, Thailand. All seeds were harvested at maturity stage from month of November to December, 2013. Heat treatment was used to break the dormancy of 'Knaow Jhaow Doi' by drying the seed in 50 ℃ for four days. The seeds were then kept in a paper envelope. Four storage conditions were used in this study consisting of room temperature (RT), room temperature with silica gel (RT & Silica), 4 ℃, and 4 ℃ with silica gel (4 ℃ & Silica). Silica gel was added in a storage box to absorb the moisture.

B. Seed Germination Test

Seed germination tests were performed by standard germination test. Four replicate experiment and 100 seeds

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per replication were conducted. Seeds were surface sterilized by soaking in 1% sodium hypochlorite (NaCIO) for 10 minutes. Seeds were then rinsed in sterile water for three times. Paper towel was moistening with water. The 100 seeds were arranged approximately one inch from the top of paper towel and ½ inch space between seeds. Another wet paper towel was laid on top of the first and then rolled together. The rolls of paper towel were placed together in air tight container and incubated at 30±5 ℃ for 7 days with 12 h light/12 h dark photoperiod. Seedlings were evaluated seven days after incubation and then every three days for two weeks. Seeds and seedlings were grouped into four characteristics including normal seedling, abnormal seedling, Fresh seeds, and dead seeds. Normal seedlings are seedling that have essential structures including root and shoot. This indicated their ability to provide nature plant under favorable condition. While, abnormal seedlings are seedling that exhibited some form of growth but missing essential structures (shoot or root) to maintain a healthy plant. For seeds that have imbibed water, appear firm and fresh but failed to germinate were considered as fresh seed. As for dead seeds are seed that cannot produced any part of seedling. Numbers of normal seedling were use to calculated germination percentage (GP) following formula; GP = (number of seed germination/number of seed on tray) *100.

C. Seed Viability Test

Seed viability tested were performed in three replications and ten seeds per replication. Seeds were soaking in water overnight, and then dissected longitudinally with a razor blade. One half of seed that contained a complete embryo was placed in 1.0% of 2,3,5 triphenyl tetrazolium chloride (TZ) solution for two hours. Seeds were then rinsed in water and evaluated under stereo microscopic. Viable seed is characterized by tissue that produce normal red color and resist the penetration of tetrazolium. Unstained seeds refer to a non- viable (non-function) tissue as established by abnormal staining characteristics and/or lack of tissue turgidity.

D. Statistical Analysis

Statistic analyses were performed using Statistical Package for the Social Sciences (SPSS).

III. Results and Discussion

A. Seed Dormancy on *O. sativa* var 'Knaow Jhaow Doi' and *O. sativa* var 'Mae Suai'

Viability and germination test were performed on freshly harvested seeds of *O. sativa* var 'Knaow Jhaow Doi' and *O. sativa* var 'Mae Suai'. Based on the results from TZ test, 'Mae Suai' is 100 % viable, while the 'Knaow Jhaow Doi' has only 60 % viability. On the other hand, the germination percentage of 'Mae Suai' and 'Knaow Jhaow Doi' are 73.33 and 56.50, respectively. This indicates that some of the 'Knaow Jhaow Doi' seeds are dormant; therefore, we applied a heat treatment to break the dormancy of the 'Knaow Jhaow Doi' seed. As shown in Fig. 1 and Fig. 2, the percentage of seed viability and percent germination in the 'Knaow Jhaow Doi' are slightly increased after a heat treatment. However, the dormancy of 'Knaow Jhaow Doi' is still evidence up to four months after harvest; thus, a higher percentage of seed viability and seed germination were observed during the five to eight months after harvest. For instance, seeds that was stored at 4 ℃ from one to four months after harvest have a percent viability of 50 to 76.70% and a germination percentage of 34.50 to 59.00%, where as seed viability and seed germination during five to eight months after harvest are 86.70 to 90.00% and 63.00 to 77.75%, respectively (Fig. 1 and Fig. 2).

Seed dormancy is often found in Indica rice and it can be dormant for several weeks depending on variety and harvest condition [10]-[12]. For instance, seeds from upland rice varieties, 'Masria' and 'Bahagia', have dormancy period from 70.5 to 83 days [13]. In our experiment, 'Mae Suai' variety did not show any dormancy as indicated by high percent of seed viability and percent of normal seedling from o to seven months after being harvested.

On the other hand, 'Knaow Jhaow Doi' seeds are dormant and even heat treatment was treated but data showed that some seed were dormant for approximately 120 days. Although, the other techniques such as 100 mg gibberellic (GA_3) and 0.2% potassium nitrate (KNO_3) also were applied with 'Knaow Jhaow Doi' but no significant difference found among all techniques (data not show).

B. Effect of Storage Condition on Seed Viability and Seed Germination

As expected, the viability of seeds stored at room temperature drop significantly at eight months after being harvested in both varieties (Fig. 1). Although, we could perform seed germination tests in 'Mae Suai' seeds only from one month to seven months after harvest due to lower amounts of seed (Table I). But based on viability results of this variety, we draw a hypothesis that lower amounts of 'Mae Suai' seeds will germinate after eight months from harvested. Similarity, at eight months after harvest, 'Knaow Jhaow Doi' seeds that were stored in an inappropriate condition (room temperature) were not able to germinate as shown in 0% normal seedling and 100% Fresh seed (Table II). These data suggested that in this storage condition, seeds were constantly exposed to high temperature and high humidity which resulted in seed deterioration.

Silica gel was added to absorb excess moisture, but seed deterioration was still evident in the 'Mae Suai' seed. As shown Fig. 1, seeds that were stored at room temperature with silica gel had only 16.70% viability. On the other hand, 'Knaow Jhaow Doi' seeds that were stored in this condition showed 90 % viability. This data suggested that silica gels that were added in to the container are able to prevent seed deterioration of 'Knaow Jhaow Doi'. Although, lower temperature and low humidity (4 ℃ with silica gel) is known as the best condition for seed storage, but no significant difference of germination percentage and percent viability found in seed that store at room temperature with silica gel, 4 ℃

and 4℃ with silica gel at twelve months of being harvested (Fig 1, Fig. 2 and Table II).

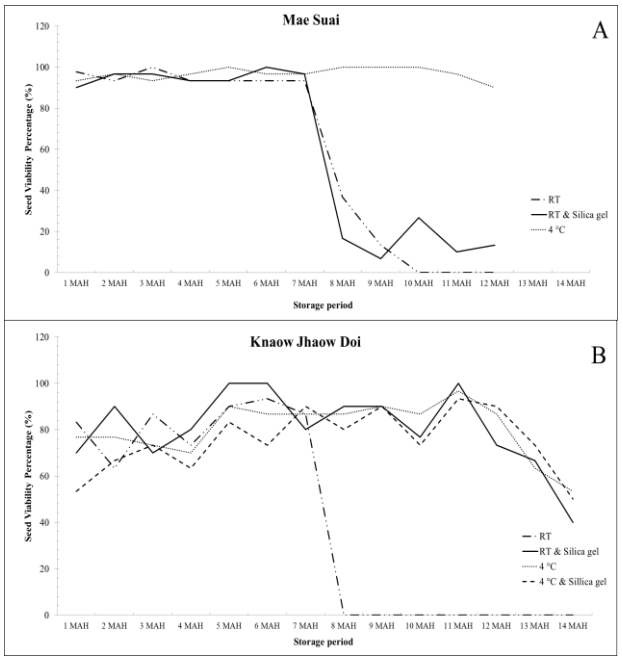

Figure 1. Seed viability percentage of (A) *O. sativa var* 'Mae Suai' and (B) *O. sativa var* 'Knaow Jhaow Doi' in each storage conditions for 12 months and 14 months after being harvested, respectively

Even though, room temperature with silica gel, 4℃ and 4℃ with silica gel are able to delay seed deteriorative process in upland rice seed but for only a select period of time. Seed viability of both varieties was decreased at thirteen months after harvesting as shown in Fig. 1. Interestingly, in all three storage conditions at thirteen and fourteen months after they were harvested, the number of fresh seeds slightly decreased (1.75 to 25.25%) while number of abnormal seedlings and dead seeds slightly increased to 21.25 – 38.00% and 14.50 to 47.50%, respectively (Table II). This could be explained by the possibility of a fungal infection in seeds that was stored for a long period of time.

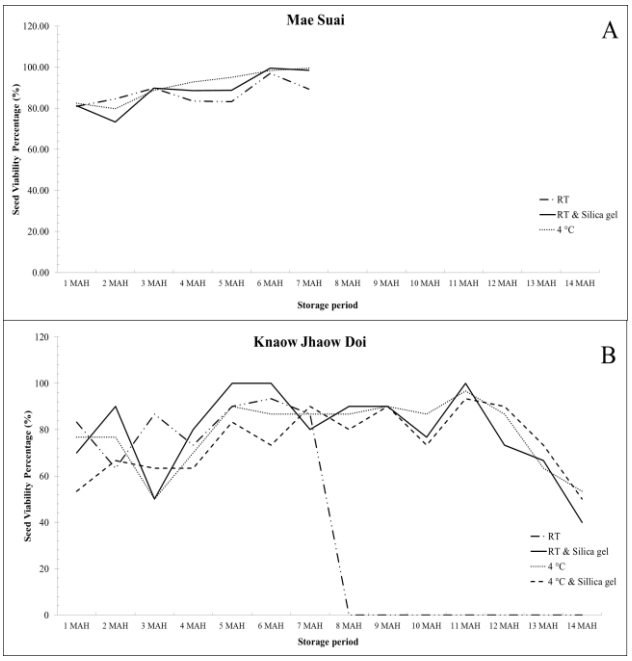

Figure 2. Germination percentage of (A) *O. sativa var* 'Mae Suai' and (B) *O. sativa var* 'Knaow Jhaow Doi' in each storage conditions for 7 months and 14 months after being harvested, respectively

TABLE I. PERCENTAGE OF NORMAL SEEDLING, ABNORMAL SEEDLING, FRESH SEED, AND DEAD SEED OF *O. SATIVA VAR* 'MAE SUAI'

Storage condition	Storage period						
	1 MAH	2 MAH	3 MAH	4 MAH	5 MAH	6 MAH	7 MAH
Normal seedling (%)							
RT	81.00±3.37	84.50±8.06	89.75±3.50	83.50±5.74a	83.25±3.30a	97.00±2.16	89.25±3.30a
RT & Silica	81.25±0.96	73.25±3.51	89.75±6.13	88.50±2.52ab	88.75±1.50a	99.50±0.58	98.50±0.58b
4 °C	82.50±9.40	79.75±7.18	88.75±2.50	92.75±2.99b	95.00±2.16b	98.25±0.96	99.50±0.58b
Abnormal seedling (%)							
RT	12.00±2.16	9.00±4.32a	4.25±1.50	7.50±1.29ab	6.25±2.06b	0.50±0.58	2.25±0.96b
RT & Silica	9.75±1.89	21.5±1.73b	4.5±1.91	9.75±2.22b	8.50±0.58b	0	1.25±0.50a
4 °C	8.00±4.16	11.75±2.50a	5.50±3.00	4.00±2.16a	2.75±0.96a	0	0.50±1.00a
Fresh seed (%)							
RT	2.75±1.71	1.75±1.50	1.25±1.89	2.50±1.73	1.75±0.96	1.50±1.91	8.25±2.87b
RT & Silica	1.75±0.96	2.25±1.26	1.25±1.89	1.00±0	1.50±0.58	0	1.25±0.50a
4 °C	3.00±0.82	3.75±2.06	2.50±1.00	1.25±0.50	1.50±1.29	1.00±0.82	0.50±0.58a
Dead seed (%)							
RT	4.25±0.65	4.75±3.86	4.75±2.36	6.50±3.00b	6.75±1.71b	1.00±1.41	0.25±0.50
RT & Silica	7.25±0.96	2.75±0.96	4.50±3.11	0.75±0.50a	1.25±0.96a	0.25±0.50	0
4 °C	6.50±4.73	4.75±3.77	3.25±0.96	2.00±1.41a	0.75±0.50a	0.75±1.50	0
*MAH = Month After Harvest							

TABLE II. PERCENTAGE OF NORMAL SEEDLING, ABNORMAL SEEDLING, FRESH SEED AND DEAD SEED OF *O. SATIVA VAR* 'KNAOW JHAOW DOI'

Storage condition	Storage period						
	1 MAH	**2 MAH**	**3 MAH**	**4 MAH**	**5 MAH**	**6 MAH**	**7 MAH**
Normal seedling (%)							
RT	30.75±9.95	56.50±8.89	63.00±10.07	64.75±4.86	71.25±2.63	73.25±2.63	69.75±2.50a
RT & Silica	42.25±5.74	54.50±4.80	68.50±3.87	60.00±4.08	67.25±3.86	76.00±6.00	78.50±5.80b
4 °C	34.50±3.42	57.25±8.66	65.00±4.97	59.00±4.69	70.25±1.71	75.25±4.11	77.75±3.40ab
4 °C & Silica	30.00±11.63	59.50±3.70	69.50±5.51	64.25±6.95	70.50±2.38	75.75±4.65	85.00±3.65b
Abnormal seedling (%)							
RT	23.25±9.22	10.00±2.94	8.25±1.50	6.25±2.22	5.25±0.96	4.25±3.95	3.00±2.58
RT & Silica	25.75±3.86	13.25±3.40	7.25±1.26	3.25±1.50	3.75±2.22	2.00±1.41	1.00±1.41
4 °C	28.00±6.00	16.50±3.70	8.50±2.52	7.00±1.73	7.00±3.56	0.25±0.50	1.50±2.38
4 °C & Silica	34.00±14.35	13.25±2.75	6.00±0.82	4.67±1.15	4.00±1.41	1.75±1.71	0.50±1.00
Fresh seed (%)							
RT	25.50±3.79	23.50±7.05	13.00±3.37	17.75±4.43	14.75±3.50	21.75±3.40	27.25±0.50b
RT & Silica	22.00±4.08	23.75±3.59	10.75±3.20	19.75±2.63	17.25±3.86	21.00±5.10	20.00±4.55a
4 °C	20.25±2.22	16.50±6.61	12.50±2.52	15.00±2.94	15.25±2.50	21.25±3.50	20.50±2.38ab
4 °C & Silica	18.75±3.30	20.25±1.71	10.00±4.40	17.50±4.20	17.75±2.22	23.75±4.79	0.25±0.50a
Dead seed (%)							
RT	20.50±15.67	10.00±6.78	15.75±6.85	11.25±2.06a	8.75±3.86	0.75±0.96a	0
RT & Silica	10.00±3.65	8.50±3.70	13.50±3.11	17.00±2.71ab	11.75±2.99	1.00±1.41ab	0.50±1.00
4 °C	17.25±6.13	9.75±3.59	14.00±3.37	20.50±3.32b	7.50±3.00	3.25±0.96b	0.25±0.50
4 °C & Silica	17.25±2.50	7.00±2.16	14.50±3.42	14.50±4.43ab	7.50±3.20	1.75±1.26ab	0.50±0.58
	8 MAH	**9 MAH**	**10 MAH**	**11 MAH**	**12 MAH**	**13 MAH**	**14 MAH**
Normal seedling (%)							
RT	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
RT & Silica	71.50±5.51c	70.25±3.30b	72.50±5.20b	67.25±12.04b	67.00±6.58b	22.25±2.87b	29.00±4.55b
4 °C	63.00±5.48b	81.00±3.83c	69.75±5.19b	63.75±6.08b	67.50±5.26b	25.25±7.14bc	30.75±13.57b
4 °C & Silica	69.25±1.89bc	82.75±1.89c	72.00±7.44b	65.75±2.22b	69.25±3.50b	35.00±5.77c	29.50±7.14b
Abnormal seedling (%)							
RT	0	0.00a	0	0.00a	0.00a	0.00a	0.00a
RT & Silica	4.50±3.87	3.75±0.50b	0	2.25±2.63a	2.50±1.73b	38.00+4.76c	20.25±6.85b
4 °C	3.00±1.63	0.00a	0	7.25±2.06b	6.00±0.82c	27.75±3.86b	23.50±5.00b
4 °C & Silica	3.25±0.96	1.75±1.71a	0	1.50±3.00a	3.00±1.41b	21.25±2.75b	23.50±7.23b
Fresh seed (%)							
RT	100.00c	100.00c	91.50±3.11b	100.00b	100.00b	84.00±2.94b	82.00±4.97b
RT & Silica	24.00±4.69a	26.00±3.74b	27.50±5.20a	30.50±11.24a	27.25±5.85a	25.25±2.38a	3.25±1.71a
4 °C	34.00±4.55b	19.00±3.83a	30.25±5.19a	29.00±4.97a	22.25±5.68a	19.25±6.40a	3.25±1.71a
4 °C & Silica	27.00±1.41ab	15.50±2.38a	28.00±7.44a	32.75±3.30a	24.75±3.20a	14.00±3.65a	1.75±0.96a
Dead seed (%)							
RT	0	0	0	0	0.00a	16.00±2.94	18.00±4.97a
RT & Silica	0	0	0	0	3.25±2.36b	14.50±0.00	47.50±5.88b
4 °C	0	0	0	0	4.25±0.50b	27.75±2.75	42.50±9.75b
4 °C & Silica	0.50±1.00	0	0	0	3.00±1.41b	29.75±4.99	45.25±10.69b
*MAH = Month After Harvest							

IV. Conclusion

Seed deterioration has a big impact on seed quality as well as crop stand. Un-appropriate seed storage (room temperature with high humidity) will provide negative effects on seed quality; therefore, upland rice seed is not recommended to store at room temperate condition unless seed will be used before seven months after storage. On the other hand, storage of seed in low temperature is highly recommended. No significant difference found among room temperature with silica gel, 4℃ and 4℃ with silica gel in one variety of upland rice seed. This data suggests that upland rice seeds can be stored at room temperature with silica gel to absorb moisture and may not provide a negative effect on their quality. This condition is a practical implication, as it is cost effective and easy to handle. Nevertheless, seeds must be used before thirteen months after they were harvested in any storage condition(s).

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