GRAIN AND SEED QUALITY OF MANAWTHUKHA RICE (*Oryza sativa* L.) AS AFFECTED BY DIFFERENT STORAGE CONTAINERS AND STORAGE DURATIONS

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Agronomy)

Department of Agronomy
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The thesis attached hereto, entitled "**Grain and Seed Quality of Manawthukha Rice (*Oryza sativa* L.) as Affected by Different Storage Containers and Storage Durations**" was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Agronomy)**.

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DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS,

U MYA SHWE AND DAW OHN SHWE

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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 rice 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 factor B with three storage durations: no storage, two months storage, and four months storage. Seed samples were stored at ambient conditions. In both storage seasons, head rice yield and 1000 grain weight were significantly different due to variation in moisture content of stored seeds as an effect of different storage containers and storage durations. Milling yield, germination percentage, germination index and seedling vigor index highly differed by the effect of storage duration except the milling yield in summer rice storage. Amylose content, gelatinization temperature and elongation ratio increased, and gel consistency decreased with storage duration in all treatments. However, the rates were higher in four months storage with the exception of gelatinization temperature and gel consistency. Head rice yield showed a negative correlation with moisture content and 1000 grain weight. Positive correlations were found among germination percent, germination index and seedling vigor index as well as among amylose content, elongation ratio and gelatinization temperature. Gel consistency showed a negative correlation with amylose content, elongation ratio and gelatinization temperature. Based on the results, grain and seed quality were significantly influenced mostly due to the effect of storage duration rather than storage container for a period of four months. Air tight tin bin can maintain stable grain moisture along the storage duration than other containers. Four months storage with air tight tin bin gave the highest grain quality in terms of head rice yield. Woven plastic bag gave the highest seedling vigor index in seed quality.

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CHAPTER I
INTRODUCTION

Rice is the world's single most important foodstuff as well as the staple food for over the billion of people in most of the countries. It is an important and nutritionally vital food commodity that feeds more than half of the world's population (Deepak and Shukla 2011). Moreover, rice is accounting for about 93 percent of the total food produced, about 70 percent of average calorie intake and 35 percent household expenses. Rice production is the largest provider to farm income, while associated trade and business are important sources of rural non-farm income (Ahmed 2001). It is grown on nearly 146 million hectares, more than 10 percent of total cultivated land. Therefore, total world paddy production is about 535 million tons. Ninety seven percent of the world's rice is grown by developing countries, mostly in Asia (IRRI 1997). In addition, 89 percent of the world's harvested rice is grown by Asian farmers accounting for 91 percent of global rice production (Ray 1999).

In Myanmar, rice is important in national and international trade with political and social implications. Regarding the food crop production in Myanmar, actual paddy sown area in 2015-2016 was 7.21 million hectares with the average yield of 3.94 metric tons per hectares and production was reached at 28.21 million metric tons, rice is self-sufficient and thus it is exporting surplus of rice approximately more than a million ton every year. Among the rice varieties which are currently growing in Myanmar, Manawthukha rice variety belonging to Letywezin group was sown 1.125 million hectares during 2015-2016 monsoon season and 94.1 thousand hectares in summer season (MOALI 2016).

In Southeast Asia, most rice is consumed as fully milled white rice by steaming or cooking in water and served in a bowl at a meal in the home or away from home at a restaurant or cafeteria. Such rice is the most important food throughout the region; however, there are other uses for rice, such as for seed, animal feed, and food manufacturing purposes, as well as waste and loss (USDA 2012).

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. Once well adapted named varieties are made available to farmers, the seed can be readily multiplied and distributed through informal farmer-to-farmer mechanisms (Glenn et al. 2013).

“Physiological quality of seed refers to the ability of a seed to germinate and includes components like germination capacity, viability, vigor and characteristics related to dormancy” (Hasanuzzaman 2015). Quality characteristics in rice may be categorized into three broad areas (1): physical characteristics include moisture content, shape, size, whiteness, translucency, chalkiness, head rice, broken rice, brewers, green kernels and yellow kernels. (2): physicochemical characteristics of rice include amylose content, protein content, gel consistency, volume of expansion of cooked rice, water absorption, and cooking time. (3): The organoleptic of cooked rice include color, aroma, hardness, stickiness, and consistency (DAWN 2001).

Storage is essential for food security or as a product bank for exchange into cash when required (Mejia 2003). Grains are stored by farmers for their consumption or for seed purposes. Traders and marketing agencies store grains for financial gain. The overall objective of grain storage is to preserve the quality, including nutritive value, and to keep the grains in good condition for marketing and processing. Storage of food grains, a component of postharvest operation, is an ongoing challenge for both industrialized and developing countries. Storage of rice is necessary to reduce problems during crop failure or poor yield in the following year (Chakraverty et al. 2003).

A proper storage of rough rice is the key factor in maintaining its qualities and the values. Physical and cooking properties such as head rice yield, pasting, volume expansion and water absorption of rice regularly changes during storage (Champagne 2004). In addition, seed storage is a vital portion of any seed program, because good stored seeds are much helpful to be yield healthy and vigorous plant. In most cases farmer’s stored seeds are badly contaminated with stored grain pests and moulds with very poor germination (Mia et al. 2000). Moreover, a good quality seed may also be seriously deteriorated if stored under sub optimal condition (Mia et al. 2004). 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 (Perdon et al. 1997; Zhou et al. 2001; Ali et al. 2005; Sultana et al. 2016). Therefore, proper storage container as well as appropriate storage duration is crucial in order to ensure good seed and grain quality in rice production.

Seed characteristics decrease under long storage condition due to aging. Aging conditions generally reduce seed vigor and germination (McDonald 1999). Aging or storing rough rice for 3-4 months after harvest also affects on grain quality. Aged milled rice has higher volume expansion and water absorption (Villareal et al. 1976). The elongation ratio of cooked rice increases during aging process (Chrastil 1990).

With interest in the effect of aging after harvesting of rice and its combined effect with different storage conditions on grain and seed quality, the study was carried out with the objectives;

1) to evaluate the grain and seed quality of Manawthukha rice variety as affected by different storage containers and storage durations, and
2) to identify the proper storage container and storage duration for quality of Manawthukha rice variety.

CHAPTER II
LITERATURE REVIEW

2.1 Importance of Rice

Rice that has been harvested from the plant with its hull (husk) intact is known as rough or paddy rice (Mary 2002). Rice was cultivated l0000 years ago in the river valleys of South and Southeast Asia and China since it served as the most important food for people. Although Asia is the major place of rice growing, it was cultivated in other continents like Latin America, Europe, some parts of Africa and even USA (Arash 2013).

Rice is a major food staple and a mainstay for the rural population and for household food security. It is mainly cultivated by small farmers in holdings of less than one hectare. Rice also plays an important role as a “wage” commodity for workers in the cash crop or non-agricultural sectors. It plays a pivotal role for the food security of over half the world population. It is also a central component of the culture of a number of communities. For those reasons, rice is considered as a “strategic” commodity in many countries, both developed and developing (FAO 2006).

There are only two major species of cultivated rice: *Oryza sativa*, or Asian rice, and *Oryza glaberrima*, or African rice. Rice can be produced under a wide spectrum of locations and climates, but, geographically, Asia is the hub of 90 percent of world production, with China and India responsible for 30 percent and 21 percent, respectively of the world aggregate (FAO 2006).

Rice is a major source of energy and an important one of protein: 100 grams of raw white rice provide 361 kcal and 6 grams of protein. Rice also contains substantial amounts of zinc and niacin. On the other hand, it is low in calcium, iron, thiamine and riboflavin and has virtually no beta-carotene (Vitamin A) (FAO 2006).

Rice is one of the cheapest sources of food energy and protein. Most rice is consumed as white polished grain, in spite of the valuable nutrient components of brown rice. About 10 billion people the world's population will depend on rice as their major food in 2025. The world will need about 880 million tons of rice in 2025 and, 92 percent more rice than was consumed in 1992. In South Asia where poverty is extensive, the need for rice is expected to double over the next 40 years. Most of the major rice producing countries is developing countries. For these countries, rice is not only their staple food, but also a major economic activity and source of employment and income for the rural population (Mejia 2003).

Rice is the major agricultural produce and staple foodstuff in Asia. Rice in Asia plays vital economic, cultural, and political roles, and in some countries it still has a significant leveraging role in the economy as it accounts for high shares of gross domestic product (GDP) and labor force. The rice sector influences agriculture and food in Cambodia, Lao PDR, and Myanmar even more than in neighboring Thailand and Vietnam, and its further development offers many benefits in the short to medium run, including a reduction in severe poverty, boosted shared prosperity, lower green house gas (GHG) emissions, job creation, particularly in the rice processing and trade industries, and better nutrition (WBG 2016).

In most of Asia, rice is grown on small, one to three-hectare farms. Farms can be less than one hectare in more densely populated countries. A typical Asian farmer plants rice primarily to meet the family's basic needs. In Brazil, 70 percent of the rice cultivated is on commercial farms of more than 50 hectares (IRRI 1997).

2.2 Rice Production in Myanmar

Seventy percent of the rural population of Myanmar engages in rice farming for their livelihood; rice is thus our life, our economics, and our politics. It is vital to keeping peace and tranquility in the country. Agriculture is the main source of livelihood of the Myanmar people. Rice is the major agriculture commodity grown in almost 50% of the cultivated area. The Ayeyarwaddy delta, central dry zone, Yangon deltaic, and Rakhine coastal areas are the major rice producing ecophysiographic regions (MOAI 2015).

In Myanmar, rice is grown during the monsoon and summer seasons in four growing zones: the delta, dry zone, coastal zone, and mountainous areas. About 80% of the annual production is harvested during the monsoon season and the remaining 20% during the summer season. About 50% of the total production comes from the delta comprised of the Ayeyarwaddy, Bago and Yangon regions. About 25% is produced in the dry zone, including Mandalay, Sagaing, and Magway regions. In general, per capita rice consumption in urban areas (180 kg/year) is lower than that in rural areas (200 kg/year) (USDA 2016). Among the nine largest rice producers in the world, Myanmar ranks sixth in area sown to rice and seventh in total production (FAOSTAT 2014).

2.3 Role of Grain and Seed Quality in Rice Production

Rice grain quality includes both physical characteristics that influence appearance and chemical characteristics that influence cooking quality. Grain quality is determined by variety; production and harvesting conditions; and postharvest handling, milling, and marketing techniques (IRRI 1992).

Quality of rice is not always easy to define as it depends on the consumer and the intended end use for the grain. All consumers want the best quality that they can afford. As countries reach self-sufficiency in rice production, the demand by the consumer for better quality rice has increased. Traditionally, plant breeders concentrated on breeding for high yields and pest resistance. Recently the trend has changed to incorporate preferred quality characteristics that increase the total economic value of rice. Grain quality is not just dependent on the variety of rice, but quality also depends on the crop production environment, harvesting, processing and milling systems (Divekar and Sharma 2016). In addition, the rice grain is very hygroscopic because of its starch content and equilibrates with the ambient relative humidity (Mary 2002).

To the farmer, grain quality refers to quality of seed for planting and dry grain for consumption, with minimum moisture, microbial deterioration and spoilage. The miller or trader looks for low moisture, variety integrity and high total and head milled rice yield. Market quality is mainly determined by physical properties and variety name, whereas cooking and eating quality is determined by physicochemical properties (Juliano 1993).

Seed may be defined as “Structurally a true seed is a fertilized matured ovule, consisting of an embryonic plant, a store of foods and a protective seed coat, a store of foods consists of cotyledons and endosperm” (Hasanuzzaman 2015).

Seed is the foundation for the production of crops that underpins farm family food security and income across Africa and Asia (Catholic Relief Services 2014). In addition, the harvesting season does not overlap the sowing season and, for this reason, the seeds are stored in order to maintain their productive potential (Souza et al. 2007). Seed quality consists of the health, physiological and physical attributes, such as the absence/presence of disease, whether grains are fully mature (and not broken), and the absence/presence of inert material such as stones or dust weeds (Walsh et al. 2014).

Seed quality begins with selecting an appropriate rice variety to suite environmental conditions, management practices, and the end use of the rice (IRRI 2009). The different rice varieties have different physical and chemical characteristics. The use of good quality seed increases crop yields, decreases the number of seeds that need to be sown, and reduces the carryover of weeds, insects and diseases. Good quality seeds also allow farmers to attain high quality end products, minimize the cost of production by ensuring high rate of survival, fast growth, and low infection by diseases and pest (Rickman et al. 2006). Raikar et al. (2011) stated that as the seed is hygroscopic in nature, seed quality is affected by variation in moisture content, relative humidity and temperature.

A superior quality seed not only increases productivity per unit area, but it also helps produce uniform crops without any admixtures, important for obtaining high prices on the market (Tokpah 2010). Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release in commercial production. If the variety does not conform to recognized standards for grain size, shape, weight, and uniformity, it is simply not considered for release (Mutters 1998).

2.4 Grain and Seed Quality Characteristics

2.4.1 1000 grain weight

A characteristic that is very important in the identification of a variety is 1000 grain weight (Tokpah 2010). It is particularly useful as a comparative indication of total milled rice yields. It provides relative measure of dockage or foreign material present, and the proportion of unfilled, shriveled and immature kernels. Although, this is a genetically-controlled parameter but may be affected by the environment in which it is growing, e.g. injudicious use of nitrogen fertilizer and also of the light conditions for photosynthesis (DAWN 2001).

2.4.2 Milling yield

Rice milling is the removal or separation of the husk (dehusking) and the bran (polishing) to produce the edible portion (endosperm) for consumption. This process has to be accomplished with care to prevent excessive breakage of the kernel and improve the recovery of the paddy (Mejia 2003).

Milling quality of rice grains is important to both, producers and consumers as the market price of rice is largely dependent on milling performance of a rice variety. Millers base their concept of quality upon total recovery and the proportion of head and broken rice on milling, therefore a variety should possess a high turn-out of whole grain (head rice) and total milled rice (Verma et al. 2012).

The conditions of milling affecting breakage are the rice temperature, moisture content during milling, the temperature and humidity of the milling environment, the degree of milling and operational conditions and mechanical settings of the machine (Luh 1980).

Milled rice kernels rapidly gain or lose moisture from the environment depending on the air temperature and relative humidity (RH) of the surrounding air, as well as the moisture content of the kernels (Lu et al. 1993). This integration into and out of the kernel causes tensile or compressive stresses to occur in the starch endosperm of the milled kernel (Stermer 1968). Depending on the moisture gradient between the kernel and the equilibrium moisture content of the surrounding air, these stresses can cause kernels to fissure during post milling operations. This in turn can lead to kernel breakage and significant reduction in head rice yield (Mary 2002).

Over exposure of mature paddy to fluctuating temperature and moisture conditions leads to development of fissures and cracks in individual kernel. Cracks in the kernel are the most important factor contributing to rice breakage during milling. This results in reduces milled rice recovery and head rice yields (Divekar and Sharma 2016).

2.4.3 Head rice yield

Head rice is characterized by milled rice with length greater or equal to 75% of the average length of the whole kernel (Omer 2013). Any milled grain that is less than three-quarters the size of the whole grain is classified as ‘broken’. Milled rice grains after removal of damaged (broken, discolored, etc.), dead and immature grains are referred to as head rice (Futakuchi et al. 2013).

Head rice yield (HRY) is a primary measure of milling quality. HRY is defined as the mass percentage of rough rice that remains as head rice (milled kernels that are at least three-fourths of the original kernel length) after complete milling. Currently, broken rice is sold at less than 60% of the price of head rice. Because of this premium for head rice relative to broken rice, HRY is a direct determinant of economic return. A number of interrelated factors during growing and processing, including kernel physicochemical properties and environmental conditions, determine rice milling quality (Siebenmorgen et al. 2006).

High head rice yield is one of the most important criteria for measuring milled rice quality. The actual head rice percentage in a sample of milled rice will depend on both varietal characteristics (i.e. the potential head rice yield), production factors, and harvesting, drying and milling process. The amount of immature paddy grains in a sample has a major affect on head rice yield and quality. The immature rice kernels are very slender and chalky and this results in excessive production of bran, broken grains and brewer’s rice (Divekar and Sharma 2016).

Rice stored in mill room is therefore likely to gain and lose moisture during storage resulting in temperature-induced and moisture-induced tensile stresses. Stress in paddy makes paddy more susceptible to assuring with subsequent reduction in head yield (Mary 2002).

2.4.4 Moisture content

One of the most critical physiological factors in successful grain storage is the moisture content of the crop. High moisture content leads to storage problems because it encourages fungal and insect problems, respiration and germination. However, moisture content in the growing crop is naturally high and only starts to decrease as the crop reaches maturity and the grains are drying (FAO 2011).

Moisture content has a marked influence on all aspects of paddy and rice quality and it is essential that paddy be milled at the proper moisture content to obtain the highest head rice yield. Grains with high moisture content are too soft to withstand hulling pressure which results in grain breakage and possibly pulverization of the grain. Grain that is too dry becomes brittle and has greater breakage. Moisture content and temperature during the drying process is also critical as it determines whether small fissures and/or full cracks are introduced into the grain structure (Divekar and Sharma 2016).

Since the life of a seed largely revolves around its moisture content, the moisture content of the seed as it is placed in storage and the relative humidity of the store are the most important factors influencing seed viability during storage. They should be dried to a safe moisture limit before placing seeds into storage, although this varies considerably by crop. Very low moisture content below 4% may also damage seeds, due to extreme desiccation. The higher the moisture content of seeds, the more they are adversely affected by higher temperatures (Walsh et al. 2014).

Moisture content plays a significant role in determining the shelf life. The shelf life is the storability of rice. If the moisture content is high and above14%, it is prone to fungus infestation. A high percentage of broken kernels occurred in the milling process at low moisture content below 8% (Henrita et al. 2016).

Moisture content is an important component of the grain and is the crucial factor affecting the storage of grain. The moisture content is taken into consideration during procurement and marketing. The growth and multiplication of insect pests and fungi, the major spoilage organisms of the grains, are dependent on the available water in the grain. Grains are hygroscopic and gain or lose water depending on the water vapor present in them and in ambient air to attain equilibrium (Chakraverty et al. 2003).

Moisture content affects rice quality in several ways. Sound dry rice can be kept for years but wet rice takes few days to rot. The moisture content of 13 percent is accepted for less than 6 months storage; where as 12 percent or less is recommended for long-term storage (DAWN 2001). High moisture grain is susceptible to deterioration by microorganisms and hence should be dried before unacceptable quality loss occurs (Divekar and Sharma 2016).

Seasonal variations in atmospheric temperature also change the temperature pattern throughout the stored rice bulk. During the summer months rice temperature in the storage is low and outside air temperatures are high. Conversely during winter months average temperature outside the rice storage is low and the rice temperature in the storage is high. The fluctuation of temperature causes accumulation of moisture due to condensation either at the top or at the bottom of rice bulk depending upon the direction of the natural convection of the air within the stored rice (Abedin et al. 2012).

2.4.5 Germination percentage

A germination test is using for estimating the viability of seed, or the percentage of grains capable of producing a plant at sowing. The more seeds that germinate, the fewer overall that need to be sown (Walsh et al. 2014). The level of germination in association with seed vigor provides a very good estimate of the potential field performance. A germination test is often the only test a farmer can conduct on the seed to determine if it is suitable for planting. By knowing the germination rate, farmers can adjust their planting rates to attain the desired plant population in the field (Gummert 2010).

Seed vigor is a more promising seed quality character reflecting potential seed germination, field emergence and seed storage ability under different conditions than standard germination. Standard germination is influenced by genetic background and environmental effects during seed development and storage conditions (Qun et al. 2007).

2.4.6 Germination index

Rapid germination and vigorous seedlings are essential if plants are to develop quickly and establish a root system to tap available water resources and obtain the maximum amount of sunlight for growth. Thus seed showing potential for early, vigorous growth is desirable. The quicker the germination, the less likely the emerging seedlings will be attacked by make use of limited moisture supplies in dry areas, pests and disease, and the more they will be able to make use of limited moisture supplies in dry areas

(Walsh et al. 2014). Seed germination and seedling growth are an energy-requiring process must rely on respiratory metabolism to supply this energy. Thus, a decrease in the rate of respiration of germinating seeds has been shown to precede a decline in the rate of seedling growth (Wilson and McDonald 1992).

Seed deterioration is an inexorable and an irreversible process. One of symptom of seed deterioration is membrane deterioration (Copeland and McDonald 1985). Disorganization of mitochondria inner membrane could be affected to seed viability (Tatipata 2009).

2.4.7 Seedling vigor index

Several factors, namely, temperature, nature of the seeds, seed moisture content, relative humidity, and so forth, influence the seed longevity during storage. There is a close relationship between the loss of seed viability during storage and the accumulation of genetic damage in the surviving seeds. Seed moisture content, temperature, and storage periods are among the main factors affecting above relationship (Bharat and Hemant 2012). Seed moisture content and storage temperature are the most important factors affecting seed longevity and vigor (Azadi and Younesi 2013). Deterioration is evidenced by decline in germination or seedling growth of seeds (Fabrizius et al. 1999). TeKrony and Egli (1990) suggested that the decrease in mitochondria respiration during storage may be associated with the peroxidative in mitochondria lipids and that these changes occurred prior to loss in seed vigor.

2.4.8 Amylose content

Amylose content is a major factor affecting rice eating texture usually, the lower the amylose content the softer the rice (Futakuchi et al. 2013). Amylose content is considered the single most important characteristic for predicting rice cooking and processing behaviour. Amylose content is directly related to water absorption, volume expansion, fluffiness, and separability of cooked grains. It is inversely related to cohesiveness, tenderness, and glossiness. The amylose acts as both a diluent and an inhibitor of swelling, especially in the presence of lipid (Zhou et al. 2001).

Bhattacharya et al. (1971) reported that the importance of percentage insoluble amylose, calculated from total amylose and soluble amylose at 100°C, as a determination of rice quality. Amylose contents determine the texture of cooked rice and rice varieties. Rice varieties with amylose content of more than 25% absorb more water and have a fluffy texture after cooking (Frei and Becker 2003). Rice texture is soft and sticky for varieties having low amylose content while rice varieties become stiff and fluffy on cooking having high amylose content (Shabbir 2008).

Based on amylose content, milled rice is classified in amylose groups, as follows: waxy (1-2%), very low amylose content (2-9%), low amylose content (10-20%), intermediate amylose content (20-25%) and high amylose content (25-33%). Generally, indica rice varieties contain more amylose than the japonica varieties (Mary 2002). Amylose content of milled rice is determined by using the colorimetric iodine assay index method (Divekar and Sharma 2016).

Starch makes up about 90% of the dry matter content of milled rice. Starch is a polymer of D-glucose linked *a*-(1, 4) and usually consists of an essentially linear fraction, amylose, and a branched fraction, amylopectin. The amylose content of starches usually ranges from 15 to 35%. High amylose content rice shows high volume expansion (not necessarily elongation) and high degree of flakiness. High amylose grains cook dry, are less tender, and become hard upon cooling. In contrast, low-amylose rice cooks moist and sticky. Intermediate amylose rice is preferred in most rice-growing areas of the world, except where low-amylose japonicas are grown (Omer 2013; Divekar and Sharma 2016).

2.4.9 Gel consistency

Gel consistency is known to influence the tenderness of cooked rice (Cagampang et al. 1973). A high value of gel consistency indicates soft texture and lower values of gel consistency indicate harder texture. When rice flour is cooked in excess water it liquefies into a gel. The consistency of the gel can be indicative of the cooked rice texture (Futakuchi et al. 2013). Gel consistency measures the tendency of the cooked rice to harden after cooling. Within the same amylose group, varieties with a softer gel consistency are preferred, and the cooked rice has a higher degree of tenderness. Harder gel consistency is associated with harder cooked rice and this feature is particularly evident in high-amylose rice. Hard cooked rice also tends to be less sticky. Gel consistency is determined by heating a small quantity of rice in a dilute alkali (Omer 2013: Divekar and Sharma 2016).

2.4.10 Gelatinization temperature

The time required for cooking milled rice is determined by gelatinization temperature or GT. Environmental conditions, such as temperature during ripening, influence GT. A high ambient temperature during development results in starch with a higher GT. GT of milled rice is evaluated by determining the alkali spreading value. In many rice-growing countries, there is a distinct preference for rice with intermediate gelatinization temperature (Omer 2013; Divekar and Sharma 2016).

The gelatinization temperature of rice starch is defined as the temperature at which nearly all the starch granules in the sample lose their birefringence (Nicholas et al. 2013). The time required to cook rice is determined by the temperature at which the crystalline structures of the starch in the grain begin to melt when heated in the presence of water. This is known as the gelatinization temperature (GT) and it ranges from 55°C to 85°C. Rice with high GT takes a longer time to cook and the cooked rice has a harder texture, while low GT rice takes a shorter time to cook and has softer to intermediate texture (Futakuchi et al. 2013).

2.4.11 Elongation ratio

Elongation ratio is the ratio of the average length of a cooked grain to that of a raw grain (Futakuchi et al. 2013). Elongation ratio is one of the most important characteristic of good rice. Some varieties expand more in size than others upon cooking length-wise expansion without a corresponding increase in girth is considered a highly desirable rice grain quality trait (Sood and Sadiq 1979). Elongation ratio is considered as a physical phenomenon and is influenced by several physicochemical and genetic factors, including genotypes, aging temperature, aging time, water uptake, amylose content and gelatinization temperature (Faruq and Prodhan 2012).

The consumers more prefer higher elongation ratio of the cooked rice than that with lower elongation ratio (Shalidullah et al. 2009). Grain elongation during cooking is affected by over cooking as this may lead to disintegration and curling of the cooked rice grain (Juliano et al. 1982). Normally, during aging of freshly harvested rice, there is an increase of rice volume expansion and water absorption observed (Keawpeng and Venkatachalam 2015).

2.5 Physciochemical Changes During Storage

The changes in physicochemical properties of aged rice are caused by changes in lipid, protein and other substances produced from enzyme activities and oxygen during storage (Charstil 1994). Physicochemical and metabolic properties of rice are influenced by numerous factors such as grain composition, cultivars, conditions of climate, cultivation, postharvesting, milling yield and cooking process (Champagne et al. 1990).

Physical and chemical changes occur during the rice storage. The eating and cooking properties are affected by the starch, protein and protein interaction, only structural changes occur rather than the change in the starch and protein interactions. These structural changes affect the flavor, texture, gelling and pasting characteristics (Zhou et al. 2002). Furthermore, 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.

Seed deterioration can be defined as the loss of quality, viability and vigor either due to aging or effect of adverse environmental factors. The rate of deterioration rapidly increases in either seed moisture content or temperature of storage (Kapoor et al. 2010). As rice has aged, the texture of the cooked rice grain became harder and less sticky than cooked fresh rice, and the aged rice showed increases in volume expansion and water absorption during the cooking process (Keawpeng and Venkatachalam 2015).

2.6 Importance of Storage in Postharvest Handling Operations

Storage is one of the most critical postharvest handling systems. Losses can easily happen if preventive measures are not taken during storage (Mejia 2003). In natural environments and when stored at ambient room conditions, seeds constantly respond to changing relative humidity, temperature and available oxygen (Walsh et al. 2014).

Consequently, it is important to develop and expand the postharvest infrastructure for better handling, processing and storage of the paddy. Unfortunately, small scale or marginal farmers often lack the resources to store large amounts of grain and do not have a large storage structure; they therefore are obliged to sell their paddy to traders or buyers immediately after harvest. They carry out no further drying, cleaning and grading because of the immediate need for cash, and there is a lack of incentive to dry because there is no significant difference in price between wet and dried paddy. The paddy is only dried for safe storage, and then only the amount necessary for consumption or a little more for cash exchange or to sell at a better price. In Asia, between 70 and 90 percent of farm-produced paddy remains in the farms and the rest is deposited in or sold to the private sector. Therefore, rice for consumption and for seed purposes, appropriate storage is required (Mejia 2003).

Seed storage is an essential segment of seed industry, In storage, viability and vigor of the seeds is regulated by many physicochemical factors like moisture content of the seed, atmospheric humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure and packaging materials.

Generally, new crop paddy should be stored for three to four months before processing. It has been found that aged rice is more capable of absorbing water as well as its sized is increased compared to the fresh one (Howell and Cogburn 2004). Azadi and Younesi (2013) reported that proper storage and optimum seed moisture content can affect the grain quality significantly. On the other hand, germination percentage, means time to germination, germination index, normal seedling percentage decrease significantly by storage. Enzyme activity decrease significantly by increased in storage.

The storage losses of rice in Asia ranged from 2 to 6% (De Padua, 1999). Hopf et al. (1976) in his mail survey on stored grain losses at farm and village level reported that 5% rice was damaged or lost in woven bamboo bin storage structure in Bangladesh. Rice is lost at 3% in the similar type of storage structures in Laos and it was 2-5% in India. When the rice is stored in sacks, the losses were 3.5-6% in India, 3-5% in Nepal, 2-3% in the Philippines, 5% in Thailand (Abedin et al. 2012).

Proper storage for seed purposes is necessary to maintain its viability. Hence, the storage structure must protect the paddy from extreme heat or cold, moisture levels at which the seed will spoil and be subjected to microbial or fungal attacks, insect pests and rodent consumption or damage. The place of storage is as important as the storage structure itself as the storage container should be protected from the weather elements and other stresses such as heat from fire and possible damage or structural failure due heavy loads (Mejia 2003). Moreover, the deterioration process in seeds involves a sequence of biochemical and physiological alterations that occur right after the physiological maturity, and which cause a reduction of vigor, resulting in loss of the germination capacity. It is not possible to avoid this process; however, it may be delayed when the storage is made under favorable conditions, mainly regarding the temperature and relative humidity (Elizabeth et al. 2013).

Generally, new crop paddy should be stored for three to four months before processing. It has been found that aged rice is more capable of absorbing water as well as its sized is increased compared to the fresh one (Kanlayakrit and Maweang 2013).

2.7 Importance and Effect of Storage Containers in Storage

Proper storage for seed purposes is necessary to maintain its viability. Hence, the storage structure must protect the paddy from extreme heat or cold, moisture levels at which the seed will spoil and be subjected to microbial or fungal attacks, insect pests and rodent consumption or damage. The place of storage is as important as the storage structure itself as the storage container should be protected from the weather elements and other stresses such as heat from fire and possible damage or structural failure due heavy loads (Mejia 2003).

The storage structure must protect the paddy from excessive heat or cold, microbial and fungal growth encoring moisture and storage insect pests and rodents. (Mejia 2003). The farmers usually store rice using traditional storage containers to meet their own consumption, facing emergency needs and seeds for the next sowing season. A portion of rice in the storage containers at farmer's level is subjected to damages or rotten by the various biotic and abiotic factors. The biotic factors includes fungi, mites, mould, insect, pest, rodent, lizards, birds, etc and the abiotic factors includes temperature, moisture content, relative humidity, thermal properties of grain and storage structure, natural calamities like heavy rain and floods, etc (Abedin et al. 2012).

Hossain et al. (2010) stated that storage container did not significantly affect all the studied parameters except 1000 grain weight and volume expansion ratio even after eighteen months storage.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site and Duration

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.

3.2 Tested Variety and Sample Preparation

Manawthukha rice variety was used as the tested variety in the current study. Rice sample were collected from local farmer in Mandalay Township, Mandalay Region. The moisture content rice samples were set to around 12.5 ± 0.2% by natural sun drying method. Six kilograms of samples was put in each container and stored at ambient condition.

3.3 Experimental Design

Experiments were subjected to a 3x3 factorial arrangement 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.

3.4 Data Collection

3.4.1 Determination on grain quality

(a) 1000 grain weight

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

(b) Milling yield and head rice yield

For determination of milling yield, one kilogram of paddy sample was milled by using a laboratory rice mill and milling yield was calculated by the following formula.

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

(IRRI 2013)

For determination of head rice yield, one kg of paddy rice was milled and head rice including whole milled rice and those that were at least three quarters in length were separated by hand. Head rice yield was calculated by using the following formula.

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

(IRRI 2013)

(c) Moisture content (wet basic)

Two grams of ground sample was taken from each replicate and dried in the oven at 130°C for 1 hour (AACC 1999). Dried samples were cooled down in the desiccators for about 20 minutes. Moisture content of the samples was determined by the following formula.

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

(IRRI 2013)

3.4.2 Determination on seed quality

Seed quality of rice samples was determined in terms of germination percentage, germination index and seedling vigor index.

(a) Germination percentage

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 10 days. The numbers of germinated seeds were recorded and germination percentage was calculated by the following formula.

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

(IRRI 2013)

(b) 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. The numbers of germinated seeds were recorded and germination index was calculated by the following formula.

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

(ISTA 1996)

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).

(c) 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.

Seedling vigor index = Germination (%) x Seedling length (mm)

(ISTA 1996)

3.4.3 Determination on physicochemical properties

Physicochemical properties of rice were determined based on amylose content, gel consistency, gelatinization temperature, and elongation ratio.

(a) Amylose content

Amylose content was determined by using the simplified iodine colorimetric procedure by the method of Juliano (1971).

Twenty whole-grain milled rice was ground in a UDY cyclone mill (sieve mesh size 60). One hundred mg of rice powder was put into a 100 ml volumetric flask and 1 ml of 95% ethanol and 9 ml of 1N sodium hydroxide were added. The contents were heated on a boiling water bath to gelatinize the starch. After cooling for one hour, distilled water was added and contents are mixed well. For each set of samples run, low, intermediate and high amylose standard varieties were included to serve as checks. Five ml of the starch solution was put in a 100-ml volumetric flask with a pipette. One mililiter of 1N acetic acid, and 2 ml of iodine solution (0.2 g iodine and 2.0 g potassium iodide in 100 ml of aqueous solution) were added and volume was made up with distilled water. Contents were shaken well and let stand for 20 minutes.

Absorbance of the solution was measured at 620 mu with a spectrophotometer such as Baush and Lomb Spectronic 20. Amylose content was determined by using a conversion factor and the results are expressed on a dry weight basis. The moisture content of the samples was essentially constant and did not need to be determined if the relative humidity and temperature of the laboratory was controlled.

Samples were categorized into low, intermediate and high based on the standard curve method of Williams et al. (1985) (Table 3.1). For the standard curve, 40 mg of potato amylose (known moisture content) were wet with 1 ml ethanol and 9 ml 1N sodium hydroxide and heated for 5-10 minutes in a boiling water bath, cooled and made up to volume. 1, 2, 3, 4, 5 ml of solution were placed with a pipette in 100 ml volumetric flasks. The solution was acidified with 1N acetic acid (0.2, 0.4, 0.6, 0.8, and 1.0 ml, respectively and treated as above. The absorbance value was plotted at 620 mu, against the concentration of anhydrous amylose (mg) and the conversion factor was determined. The dilution factor of 20 for the samples was included in the conversion factor. Starch solutions (100 mg/100 ml) prepared by the manual method may be automatically analyzed with an AutoAnalyzer. Portions of the starch solutions were transferred into the sample cups of the AutoAnalyzer and run at 70 samples/hour. A standard curve was made using rice samples of predetermined amylose content by the simplified manual method at 620 mu. A fresh working iodine solution (1.0 ml 1N acetic acid and 3.0 ml stock iodine solution diluted to 100 ml) was prepared daily.

(b) Gel consistency (GC)

Gel consistency was determined according to the method of Cagampang et al. (1973). Make certain that all the samples were stored in the same room for at least 2 days to get the same moisture content. Ten whole milled rice grains were placed in the Wig-L-Bug amalgamator and grinded for 40 seconds to give fine flour (100 mesh).

For each sample, 100 mg (±1 mg at 12% moisture) of powder was weighed in duplicate into the culture tubes, 0.2 ml of 95% ethyl alcohol containing 0.025% thymol blue in ethanol solution was added followed by shaking and 2.0 ml of 0.2N KOH addition by using a Vortex Genie mixer with speed set at 6. The mixture was then boiled in a water bath followed by cooling in ice cold water. The test tubes were covered with glass marbles (to prevent steam loss, and to reflux the samples). The samples were cooked in a vigorously boiling water bath for 8 minutes, making sure that the tube contents reach 2/3 the height of the tube. The test tubes were removed from the water bath and let stand at room temperature for 5 minutes. The tubes were cooled in an ice-water bath for 20 minutes and laid horizontally on a laboratory table lined with a millimeter paper and the length of the gel was measured in mm from the bottom of the test tube to the gel front. Hard, medium and soft gel rice varieties were included as checks. Measurement ranges and categories are shown in Table (3.2).

(c) Gelatinization temperature (GT)

Gelatinization temperature was measured based on alkali-spreading value. The alkali digestibility test was employed by the method of Juliano (1971).

Three sets of six whole milled grains without cracks were selected and placed in plastic boxes (2″ × 2″ × 1″) and soaked in 10 ml (cc) of 1.7% KOH solution. The samples are arranged to provide enough space between kernels to allow for spreading. The boxes are covered and incubated for 23 hours at 30°C in an oven or by use of ambient temperature. Starchy endosperm is rated visually based on numerical spreading scale (Table 3.3). Standard check varieties of high, intermediate and low gelatinization types of rice are included for every test.

(d) Elongation ratio

Elongation ratio was determined by using method of Azeez and Shafi (1966). Using a photographic enlarger 25 whole milled kernel's lengths was measured. These measured kernels were taken into a wire net and immersed in 20 ml of distilled water for 30 minutes. Then, the net containing 25 rice kernels were placed in boiling water for 10 minutes. Then, it 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.

3.5 Statistical Analysis

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

Table 3.1 Categories for amylose content

Class	Amylose Content (%)
Waxy	0-7
Low	8-20
Intermediate	21-25
high	>25

Table 3.2 Categories for gel consistency

Category	Consistency (mm)
Soft	> 60
Medium	40-60
Hard	< 40

Table 3.3 Numerical scales for scoring gelatinization temperature

Category	Temperature Ranges (^{o}C)	Alkali Spread
Low	55-69	6-7
High/Intermediate	70-74	4-5
High	75-79	2-3

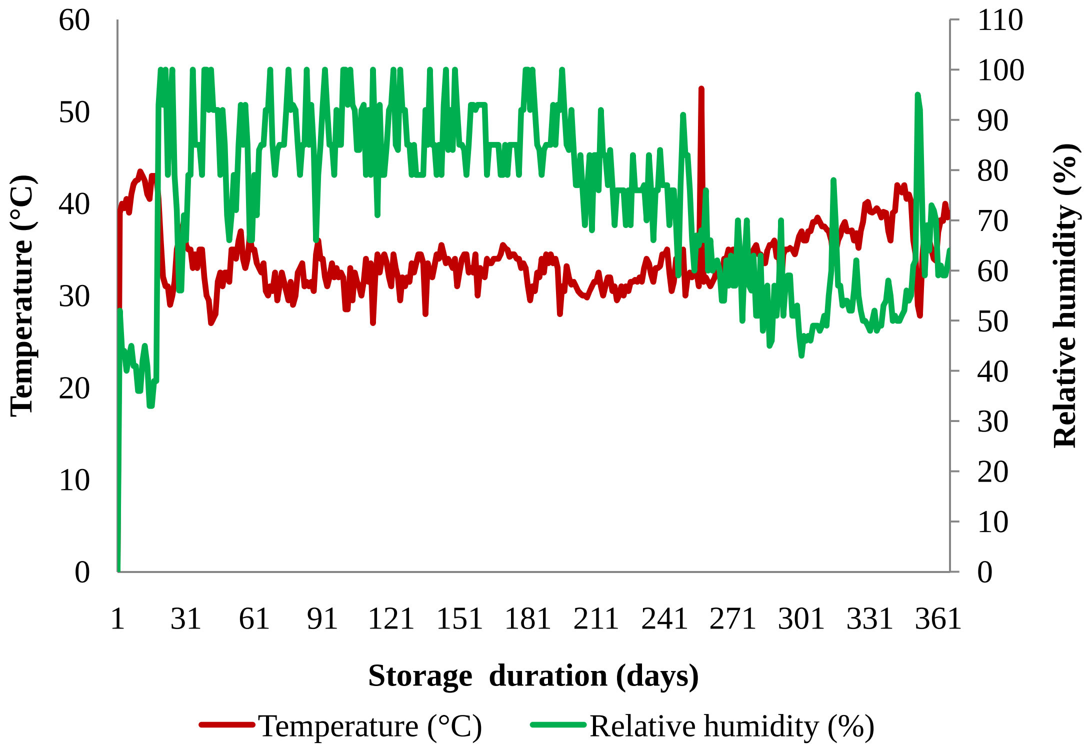

Figure 3.1 Mean daily values of temperature and relative humidity within 12 months (May 2016 to April 2017) during the storage period of study

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Summer Rice Storage Experiment

Mean effect of storage containers and storage durations on grain quality and seed quality of Manawthukha variety, summer season storage, 2016 are shown in Table 4.1 and 4.2.

4.1.1 1000 grain weight

The mean values of 1000 grain weight as affected by different storage conditions are shown in Table 4.1. Thousand grain weight of stored rice was different among three types of storage containers (Pr = 0.02). Maximum 1000 grain weight was resulted from air tight tin bin (18.28 g) followed by woven plastic bag (18.18 g). The mean 1000 grain weight of woven plastic bag was statistically similar with the other two types of storage containers. Thousand grain weight was significantly varied among the storage durations (Pr < 0.0001). This result might be due to increased moisture content of stored rice in the storage containers with the onset of monsoon during storage period. Because 1000 grain weight of rice greatly depended upon its moisture content. 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. Maximum 1000 grain weight (18.32 g) was obtained from four months storage and the lowest from no storage.

There was no interaction between storage containers and storage durations (Pr = 0 .17) (Figure 4.1). This result pointed out that the changes in 1000 grain weight of storage containers were not influenced by storage durations. By this result, 1000 grain weight increased in two months storage than no storage in all storage containers. Although, 1000 grain weight more increased in air tight tin bin and woven plastic bag after storage, it decreased in bamboo basket. However, the rate of changes was not significantly different between two months and four months storage.

4.1.2 Milling yield

Means of milling yield of rice as affected by different storage containers and storage durations are shown in Table 4.1. The milling yield was not significantly different among all the treatments of different storage containers and different storage durations. These results might be due to insufficient storage duration. The maximum milling yield was obtained from bamboo basket (61.00%) followed by air tight tin bin (60.91%) and woven plastic bag (60.45%). It was observed that milling yield decreased with increased storage durations. This may be due to the improvement in physical hardness of rice grains on storage particularly in non-air tight container. The maximum milling yield was resulted from no storage (61.15%) followed by two months storage (60.45%) and four months storage (59.69%). Similarly, Rosario et al. (2017) interpreted that on milling quality; mean values for percent whole, broken and damaged showed no differences across in different storage containers on the fourth months of storage.

No interaction was found in milling yield between storage conditions and storage durations (Pr = 0.93) (Figure 4.2). This result indicated that milling yield in different types of storage containers was not influenced by storage durations. In two months storage, milling yield in air tight tin bin and bamboo basket numerically increased (61.60%), (61.33%) however that in woven plastic bag numerically decreased (60.79%) than no storage (61.15%). In four months storage, milling yield numerically decreased in all storage containers than no storage. The maximum milling yield was found in woven plastic bag (60.78%) followed by air tight tin bin (60.23%) and bamboo basket (58.86%) numerically.

Table 4.1 Mean effects of storage containers and storage durations on grain quality of Manawthukha rice variety, summer rice storage, 2016

Treatments	1000 grain weight (g)	Milling yield (%)	Head rice yield (%)
Container			
Air tight tin bin	18.28 a	60.91	39.62 b
Bamboo basket	18.05 b	61.00	42.81 a
Woven plastic bag	18.18 ab	60.45	37.61 c
LSD $_{0.05}$	**0.16**	**2.47**	**1.89**
Duration (month)			
No storage	17.92 b	61.15	41.61 a
Two	18.27 a	60.45	40.42 a
Four	18.32 a	59.96	38.02 b
LSD $_{0.05}$	**0.16**	**2.47**	**1.89**
Pr ≥ F			
Container	0.02	0.89	< 0.0001
Duration	< 0.0001	0.50	0.002
Container x Duration	0.17	0.93	0.007
CV %	**1.01**	**4.83**	**5.61**

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

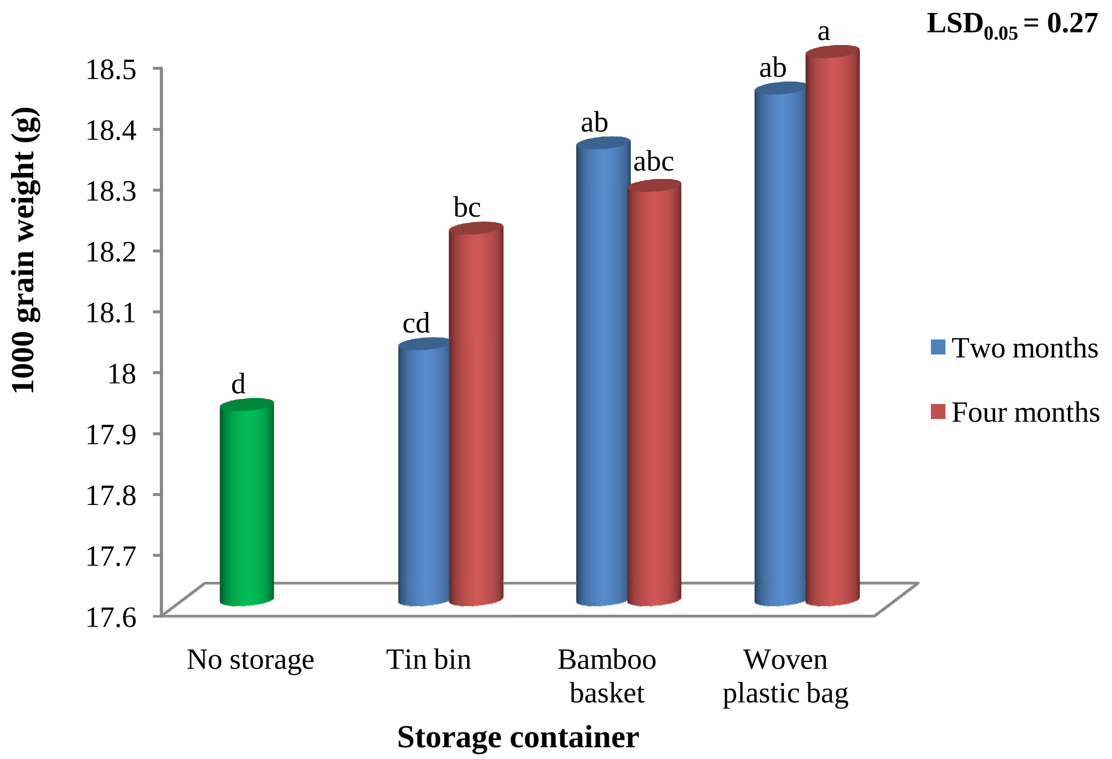

Figure 4.1 Effect of storage containers and storage durations on 1000 grain weight in summer rice storage, 2016

4.1.3 Head rice yield

Head rice yield as affected by different storage containers and storage durations is shown in Table 4.1. The results showed that there were highly significant differences in head rice yield among storage containers ($Pr < 0.0001$). Among the storage containers, bamboo basket gave the highest head rice yield (42.81%) followed by air tight tin bin (39.62%). However, woven plastic bag gave the lowest head rice yield (37.61%). There were also highly significant differences in head rice yield among storage duration ($Pr = 0.002$). Hossain et al. (2010) also found that head rice outturn was significantly affected by 18 months of storage duration. However, Thompson et al. (1990) observed that rice milling appraisal results were unaffected by storage times of 10 to 118 days prior to milling. The maximum head rice yield was resulted from no storage (41.61%) and two months storage (40.42%) which was not significantly different each other. The lowest head rice yield was resulted from four month storage (38.02%). In case of storage with woven plastic bag, two months storage gave head rice yield (40.45%) similar to that of no storage, whereas four months storage resulted in lower head rice yield (36.81%), which was not significantly different from head rice yield stored in bamboo basket for both storage durations (37.12%) in two months storage and (34.11%) in four months storage. This might be due to reduction in moisture of the grains affecting the resistance against due to fissured grains caused by moisture fluctuation during storage that occurred breakage of milled rice during milling process.

The combined effect of different storage containers and different storage conditions was significant on head rice yield ($Pr = 0.007$) (Figure 4.3). The head rice yield in air tight tin bin was almost stable along the storage and not significantly different from that of woven plastic bag in two months storage (40.45%) and no significant different with no storage (41.61%). Nevertheless, head rice yield decreased in bamboo basket with storage period (37.12%), (34.11%) and woven plastic bag in four months storage (36.81%).

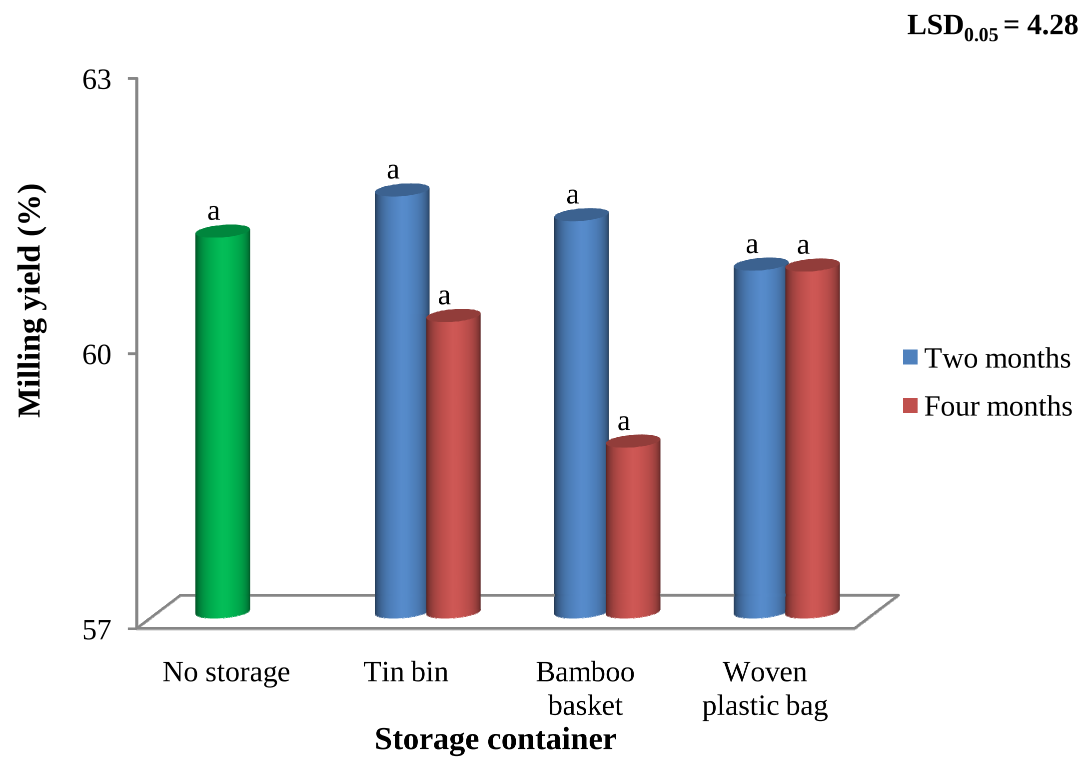

Figure 4.2 Effect of storage containers and storage durations on milling yield in summer rice storage, 2016

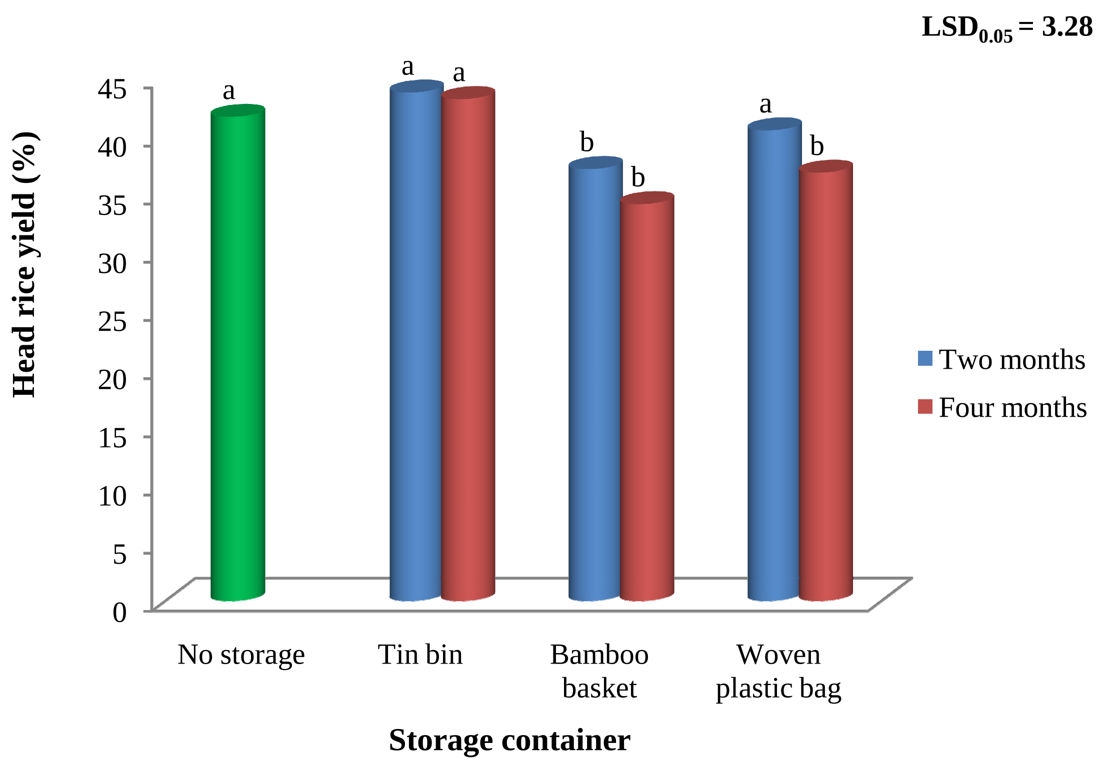

Figure 4.3 Effect of storage containers and storage durations on head rice yield in summer rice storage, 2016

4.1.4 Moisture content

The moisture content of paddy affected by different storage containers and storage durations is shown in Table 4.2. The average moisture content of rice with no storage was (12.69%). The moisture content of stored rice significantly varied among types of storage containers (Pr < 0.0001). Among the storage containers, woven plastic bag gave the highest grain moisture (13.03%) followed by bamboo basket (12.74%) but air tight tin bin gave the lowest grain moisture content (12.51%). Air tight tin bin could maintain their grain moisture content relatively stable. The other two containers were not air tight and therefore moisture fluctuation might happen according to their equilibrium along storage. Chowdhury et al. (2014) stated that the lowest moisture content was observed in the seeds stored in the Biscuit tin during the same storage period.

There was also significant difference in moisture content with storage durations (Pr < 0.0001). Chowdhury et al. (2014) recorded that the moisture content of the seed responded significantly to the storage period. Grain moisture content decreased after two months storage (12.01%) compared to no storage (12.69%), however increased (13.57%) at the end of four months. This result is supported by Dhaliwal et al. (1991) who reported that paddy stored in no air tight material under ambient conditions with the onset of the monsoon, the moisture content of that paddy increased. These results might be due to effect of environment because rice samples were stored at ambient conditions. Moreover, storage duration was synchronized during wet season. Therefore, moisture absorption of stored rice was occurred to reach their equilibrium.

The results showed significant interaction in moisture content between storage containers and storage durations (Pr < 0.0001) (Figure 4.4). The grain moisture in tin bin was almost stable showing 12.45% in two months storage and 12.38% in four months storage along the storage duration, however slightly decreased as compared to the seed moisture content with no storage (12.69%). Tin bin is a kind of air tight container; therefore its grain moisture content was almost stable throughout storage duration. However, grain moisture fluctuated in bamboo basket and woven plastic bag. The grain moisture content decreased after two months storage (11.2%), (12.39%) and increased after four months storage (14.33%), (14.00%) in bamboo basket and woven plastic bag than no storage (12.69%). These results might be due to moisture absorption and desorption occurred during storage because bamboo basket and woven plastic bag were not air tight. Dhaliwal et al. (1991) reported that the moisture equilibrated according to the temperature and relative humidity regardless of initial moisture content.

4.1.5 Germination percentage

The differences of mean effect of different storage containers and storage durations on germination percentage are shown in Table 4.2. Germination percentage was not affected by types of storage containers (Pr = 0.38). Air tight tin bin gave the highest germination percentage (96.08%) followed by woven plastic bag (96.00%) and bamboo basket (95.25%). However, significant differences of germination percentage were found in storage durations (Pr < 0.0001). The minimum germination percentage was found in the seed samples with no storage (90.50%) while the maximum germination percentage was found in two months storage (99.58%) and then it decreased in four months storage (97.25%). 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.

There was no interaction between storage containers and storage durations (Pr = 0.63) in germination percentage. This indicates that the changes of germination percentage with storage durations were not influenced by types of storage containers. Compared with no storage, germination percentage of stored seeds increased in all type of storage containers (Figure 4.5). Two months storage showed higher value of germination percentage than four months storage. Among the germination percentage, the minimum germination percentage was observed from four months storage in bamboo basket (96.00%), which was not significantly different from air tight tin bin (98.25%) and woven plastic bag (97.50%) for the same storage period. It was observed that the rice seeds stored in woven plastic bag gave the maximum germination percentage (100%) which was similar to storage in air tight tin bin (99.50%) and bamboo basket (99.25%) for two months storage. However, germination percentage of stored rice in air tight tin bin was not significantly different between two months (99.50%) and four months storage (98.25%).

4.1.6 Germination index

Germination index of rice as affected by different storage containers and durations is presented in Table 4.2. Types of storage containers did not significantly influence on germination index (Pr = 0.69). The maximum germination index was found in air tight tin bin (28.52) followed by woven plastic bag (28.50) and bamboo basket (28.07). Effect of storage duration on germination index was significantly different (Pr = 0.001). Germination index increased with storage durations, ranging from 26.93 to 29.33.

The lowest germination index was found from no storage while the maximum germination index was seen in four months storage that was statistically similar to that of two months storage. Ching (1973) stated opposite results that in aged seeds caused either by a long period of storage or a short time under unfavorable storage conditions, germination is not greatly impaired; however the vigor or growth rate of seedlings is often markedly reduced. These findings are inconsistent with the concept of Sarah (2015) that there were significant differences between the storage materials for the speed of germination (germination index) of the seeds.

No interaction was found between storage containers and storage durations (Pr = 0.31) (Figure 4.6). These result pointed out that the changes of germination index with storage duration was not governed by the types of storage containers.

4.1.7 Seedling vigor index

There was no significant difference among the storage containers and storage durations on seedling vigor index as shown in Table 4.2. Seedling vigor index was not significantly different by types of storage containers (Pr = 0.65). There was numerically difference among storage containers. The maximum seedling vigor index was found in woven plastic bag (11979) followed by bamboo basket (11771) and air tight tin bin (11680). 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 (13082) followed by two months storage (12260) however the minimum value was obtained from no storage (10088). However, Rosario et al. (2017) found that seedling vigor index was significantly different in the different storage materials on the fourth month of storage.

The results showed no significant interaction between storage containers and storage durations (Figure 4.7). This means that the changes of seedling vigor index with storage durations was not governed by types of storage containers. Seedling vigor index was relatively stable not only in each storage container but also between two months and four months storage duration, in which seedling vigor index were significantly higher than no storage. The values were 10088 in no storage, 12107 and 12845 in air tight tin bin, 12161 and 13065 in bamboo basket, and 12513 and 13336 in woven plastic bag respectively. Based on results, seedling vigor index were significantly higher in all treatment than the seedling vigor index of rice with no storage.

Table 4.2 Mean effects of storage containers and storage durations on seed quality of Manawthukha rice variety, summer rice storage, 2016

Treatments	Moisture content (%)	Germination percentage (%)	Germination index	Seedling vigor index
Container				
Air tight tin bin	12.51 c	96.08	28.52	11680
Bamboo basket	12.74 b	95.25	28.07	11771
Woven plastic bag	13.03 a	96.00	28.50	11979
LSD $_{0.05}$	**0.14**	**1.34**	**1.21**	**678.77**
Duration (month)				
No storage	12.69 b	90.50 c	26.93 b	10088 c
Two	12.01 c	99.58 a	28.82 a	12260 b
Four	13.57 a	97.25 b	29.33 a	13082 a
LSD $_{0.05}$	**0.14**	**1.34**	**1.21**	**678.77**
Pr ≥ F				
Container	< 0.0001	0.38	0.69	0.65
Duration	< 0.0001	< 0.0001	0.001	< 0.0001
Container x Duration	< 0.0001	0.63	0.31	0.97
CV %	**1.25**	**1.66**	**5.07**	**6.82**

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

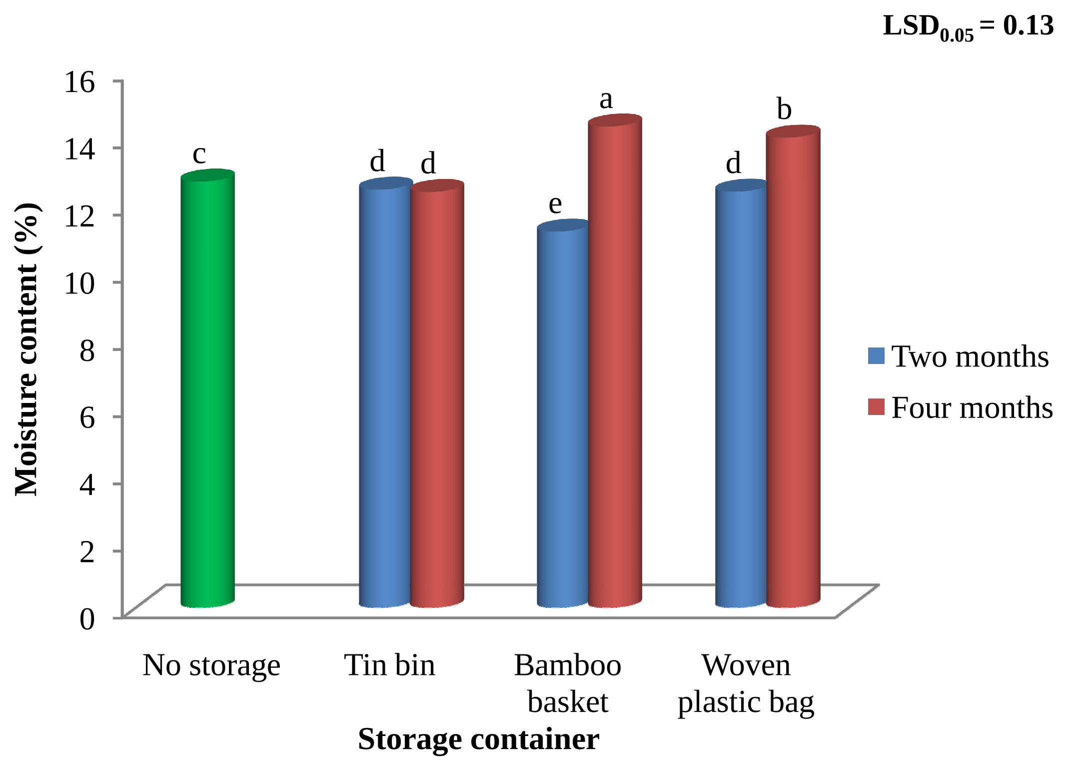

Figure 4.4 Effect of storage containers and storage durations on moisture content in summer rice storage, 2016

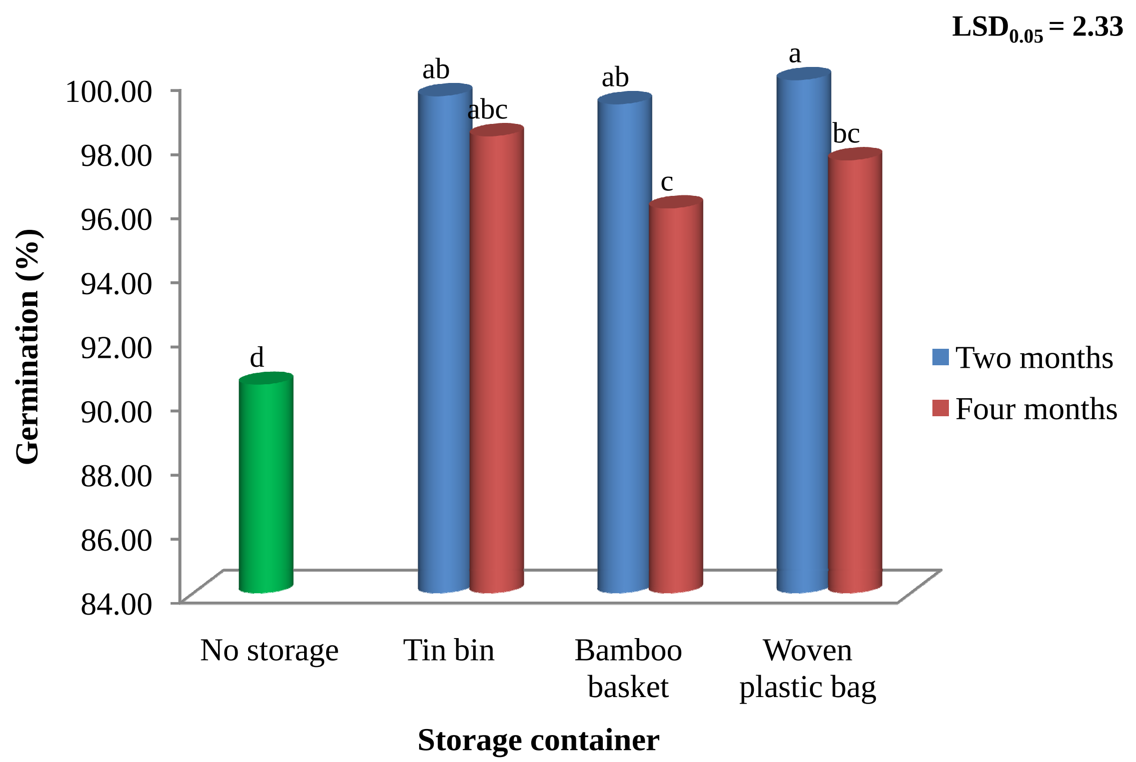

Figure 4.5 Effect of storage containers and storage durations on germination percentage in summer rice storage, 2016

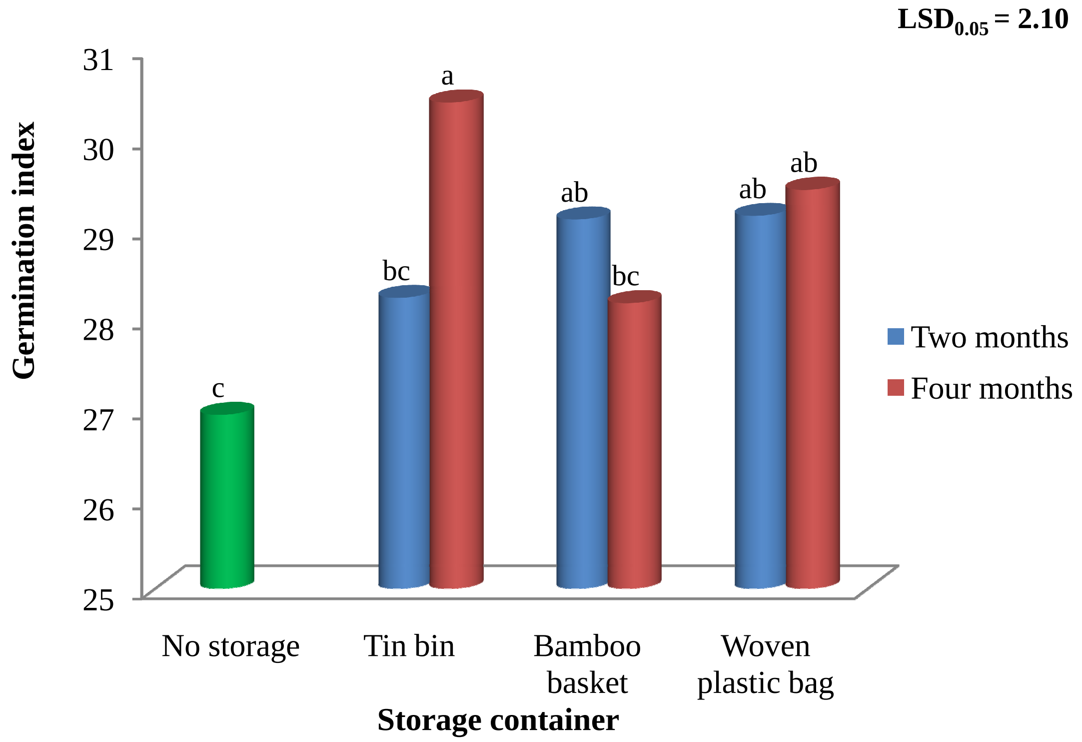

Figure 4.6 Effect of storage containers and storage durations on germination index in summer rice storage, 2016

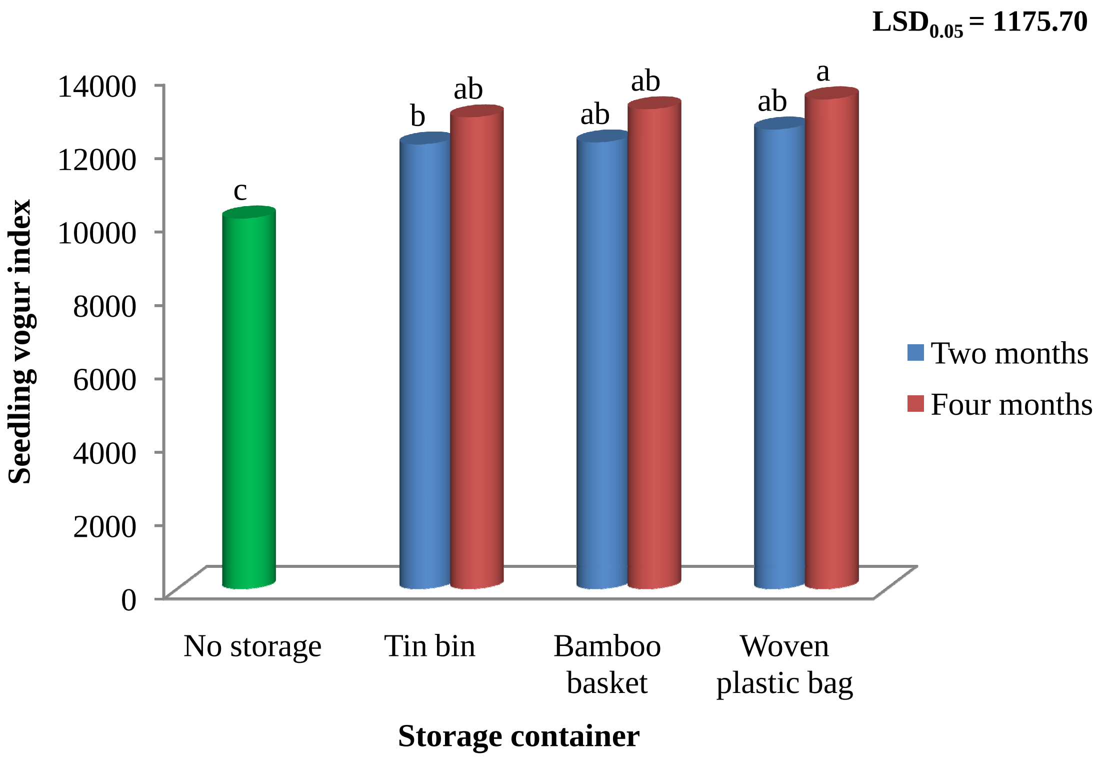

Figure 4.7 Effect of storage containers and storage durations on seedling vigor index in summer rice storage, 2016

4.1.8 Amylose content

The mean value of amylose content as affected by different storage conditions is shown in Figure 4.8. The mean amylose content in no storage was 31.00% and it is indicated as high level by the categories of Williams et al. (1985). Amylose contents slightly increased with storage durations in all storage containers. This might be due to enzymatic activity of fresh rice that is very active therefore amylose content can be well breakdown. However, enzymatic activity significantly decreased during storage and so amylose content is accumulated in stored rice. Therefore, amylose content of stored rice is usually higher than that of fresh rice. Zhou et al. (2001) mentioned that the alpha-amylase and beta-amylase activities of rough rice samples decreased significantly during storage.

At the time of two months storage amylose content slightly increased in bamboo basket and woven plastic bag, however slightly decreased in air tight tin bin. In two months storage, the maximum amylose content was obtained from bamboo basket (32.20%) followed by woven plastic bag (32.00%) and air tight tin bin (30.60%). After four months storage, amylose content increased more than two months storage in all types of storage containers. The maximum amylose content observed in air tight tin bin (33.6%) followed by bamboo basket (34.80%), and woven plastic bag (33.00%) respectively.

4.1.9 Gel consistency

Gel consistency as affected by different storage containers and storage durations is shown in Figure 4.9. The mean value of gel consistency in no storage was 46 mm. According to Cagampang et al. (1973), this value is consistent in intermediate level; however, gel consistency of stored rice decreased during storage resulting in hard level. 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).

In two months storage, among the storage containers, air tight tin bin gave the highest gel consistency (31.50 mm) followed by woven plastic bag (30.50 mm) and bamboo basket (29.50 mm). Although gel consistency slightly decreased in air tight tin bin and woven plastic bag, it remained unchanged in bamboo basket after four months storage. The maximum gel consistency was resulted from woven plastic bag (30.00 mm) followed by bamboo basket (29.50 mm) and air tight tin bin (29.00 mm). Bleoussi et al. (2010) mentioned that a high value of gel consistency indicates soft texture and lower values of gel consistency indicate harder texture. Gel consistency decreased from 6 weeks to 64 weeks of storage.

4.1.10 Gelatinization temperature

The results of gelatinization temperature in the different storage containers and storage durations are presented in Figure 4.10. Gelatinization temperature in no storage (74-75°C) is including in high/intermediate level (Juliano 1971). Gelatinization temperature distinctly increased after two months storage than no storage (75°C) in all storage containers. There were similar gelatinization temperatures among types of storage containers (80°C). In addition, it remained unchanged after four months storage in all types of storage containers as in two months storage. Gelatinization temperature of stored rice is usually higher than that of fresh rice. This might be due to physicochemical changes occurred during storage. Therefore, cooking time of stored rice is also longer than that of fresh rice. Similar findings were reported by Wattinee and Charoenrein (2014) who found that the gelatinization temperature increased with increasing time periods of rice ageing. These results indicated that the extended ageing time of rice restricted the gelatinization of starch granules.

4.1.11 Elongation ratio

Elongation ratio of rice as affected by different storage containers and storage durations is shown in Figure 4.11. Elongation ratio evidently increased in two months storage than no storage (1.6). There was totally similar elongation ratio among types of storage containers (1.8) at the time of two months storage. After four months storage, elongation ratio increased in bamboo basket and woven plastic bag, however it remained the same in air tight tin bin. Among the storage containers, bamboo basket and woven plastic bag gave the highest elongation ratio (1.9) and followed by in air tight tin bin (1.8). These 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 (Charstil 1994).

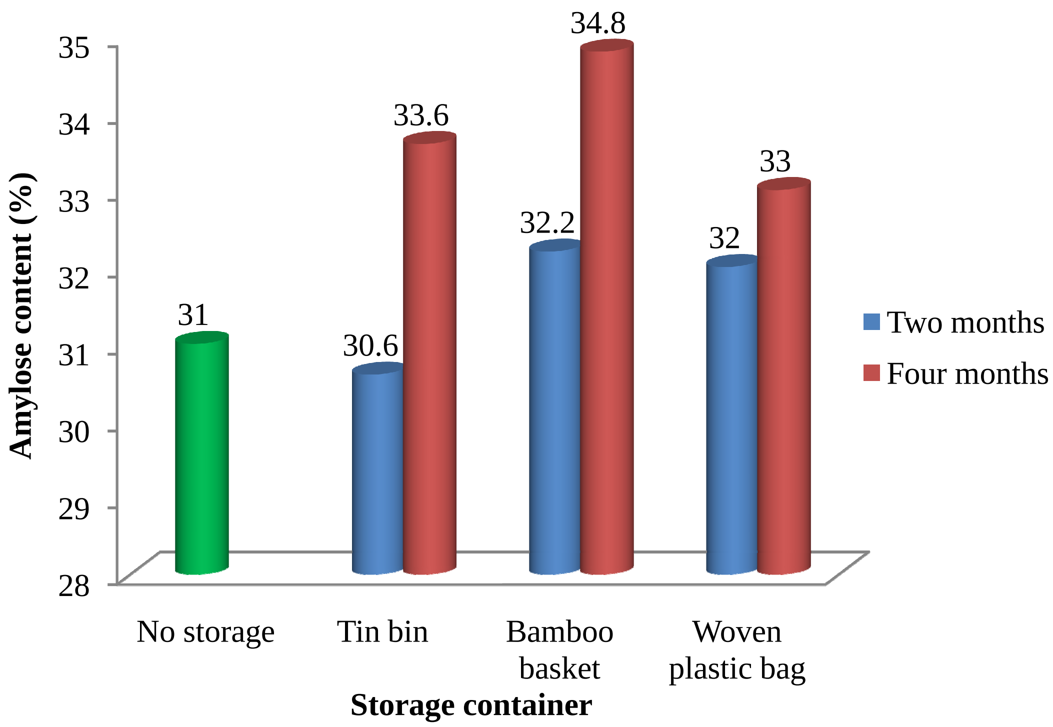

Figure 4.8 Mean values of amylose content as affected by storage containers and storage durations in summer rice storage, 2016

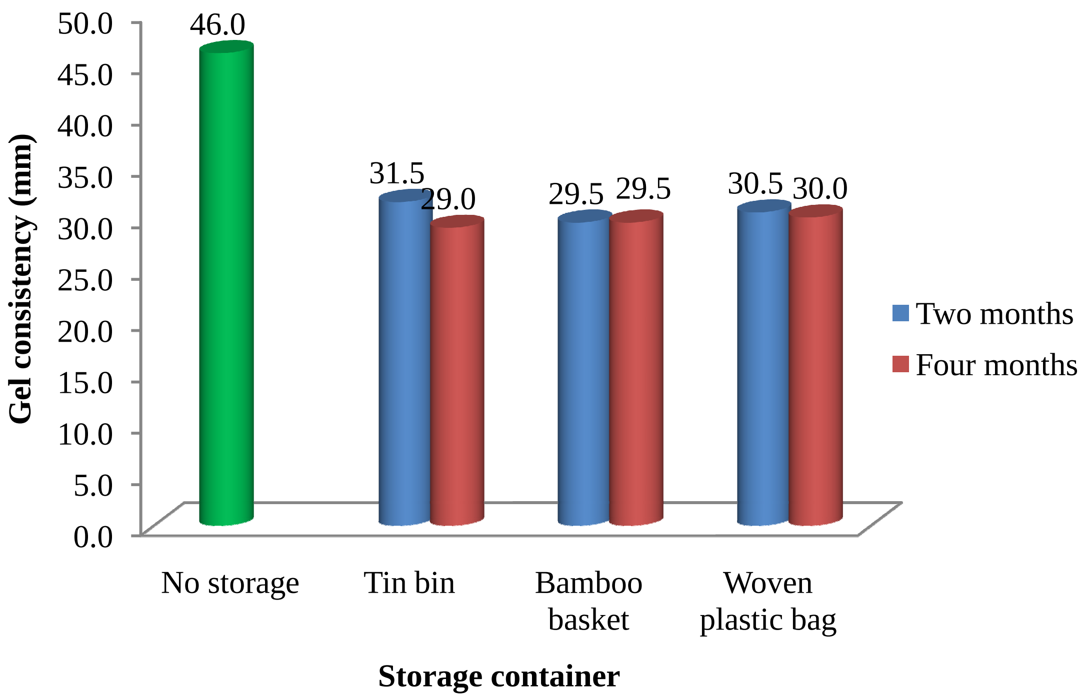

Figure 4.9 Mean values of gel consistency as affected by storage containers and storage durations in summer rice storage, 2016

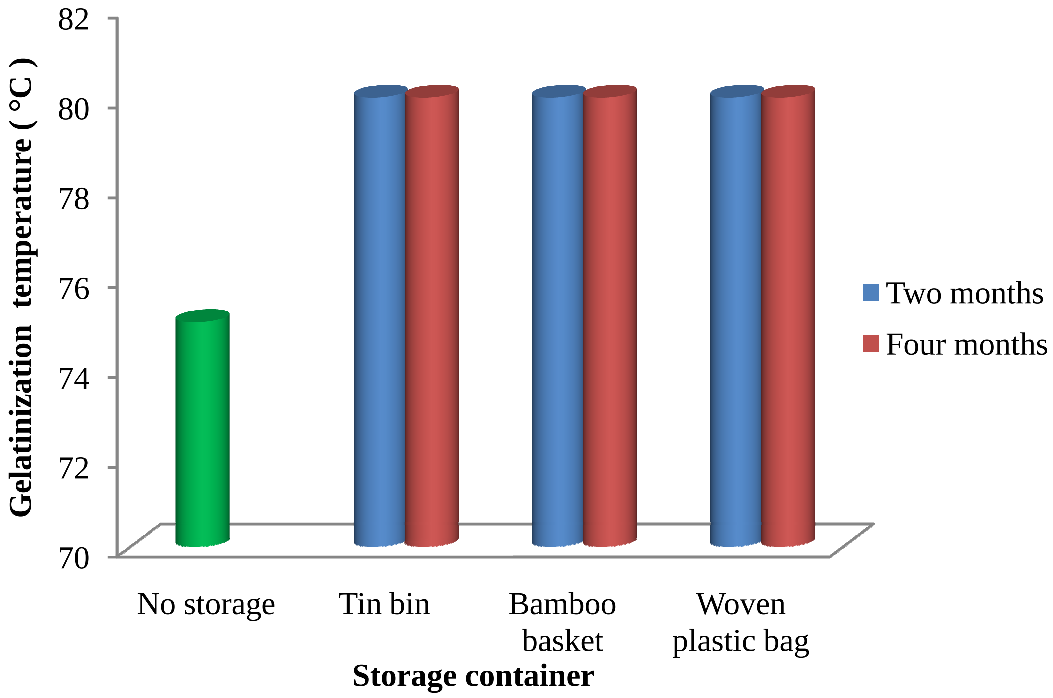

Figure 4.10 Mean values of gelatinization temperature as affected by storage containers and storage durations in summer rice storage, 2016

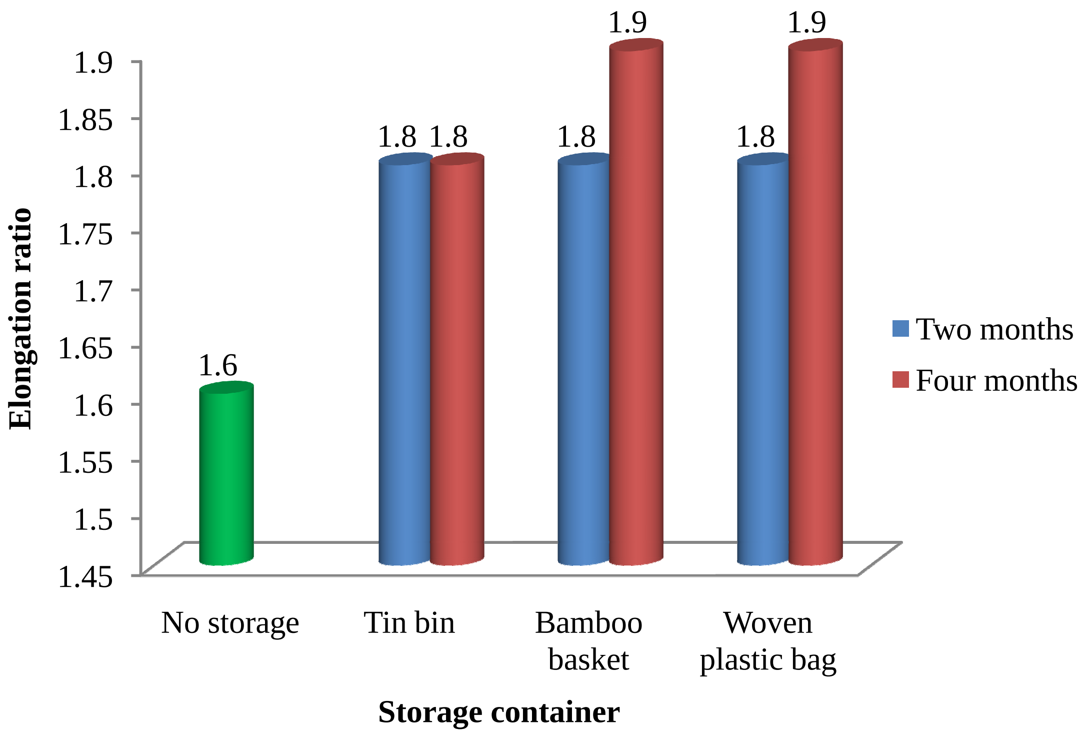

Figure 4.11 Mean values of elongation ratio as affected by storage containers and storage durations in summer rice storage, 2016

4.1.12 Correlation coefficient among grain qualities of Manawthukha rice variety as affected by different storage containers and storage durations in summer rice storage, 2016

Correlation coefficient among grain quality as affected by different storage containers and storage durations is shown in Table 4.3. There was no significant correlation among the moisture content of rice, 1000 grain weight, milling yield and head rice yield. However, among the grain quality parameters, moisture content was positively correlated with 1000 grain weight negatively correlated with milling yield and head rice yield. Thousand grain weight was also negatively correlated with milling yield and head rice yield. Milling yield was positively correlated with head rice yield. Khatun et al. (2003) found that milling yield was highly significant and positively correlated with head rice yield.

4.1.13 Correlation coefficient among seed qualities of Manawthukha rice variety as affected by different storage containers and storage durations in summer rice storage, 2016

Correlation coefficient of seed quality as affected by different storage conditions is shown in Table 4.4. Although there was no significant correlation, moisture content was positively correlated with seedling vigor index, however negatively correlated with germination percentage and germination index. Chowdhury et al (2014) stated that the less the moisture content of rice is, the more germination percentage get. There were significantly and positively correlations among germination percentage, germination index, and seedling vigor index at 1% level.

4.1.14 Correlation coefficient among physicochemical properties of Manawthukha rice variety as affected by different storage containers and storage durations in summer rice storage, 2016

Correlation coefficient of physicochemical properties as affected by different storage conditions is shown in Table 4.5. Amylose content was significantly and positively correlated with elongation ratio and negatively correlated with gel consistency at 5% level. Similarly, Khatun et al. (2003) observed that amylose content was highly significantly and positively correlation with elongation ratio and negatively associated with gel consistency. Although there was not significantly difference, positive correlation was seen between amylose content and gelatinization temperature. Gel consistency showed a significantly and negatively correlation with elongation ratio and gelatinization temperature at 1% level. Gelatinization temperature was significantly and positively correlated with elongation ratio at 1% level.

Table 4.3 Correlation among grain quality parameters as affected by storage containers and storage durations in summer rice storage, 2016

Parameters	Moisture content	1000 grain weight	Milling yield	Head rice yield
Moisture content	1			
1000 grain weight	0.17	1		
Milling yield	-0.66	-0.36	1	
Head rice yield	-0.48	-0.62	0.60	1

*Significant difference at 5% level, **Significant difference at 1% level

Table 4.4 Correlation among seed quality parameters as affected by storage containers and storage durations in summer rice storage, 2016

Parameters	Moisture content	Germination percentage	Germination index	Seedling vigor index
Moisture content	1			
Germination percentage	-0.18	1		
Germination index	-0.09	0.84**	1	
Seedling vigor index	0.29	0.85**	0.86**	1

*Significant difference at 5% level, **Significant difference at 1% level

Table 4.5 Correlation between physicochemical properties as affected by storage containers and storage durations in summer rice storage, 2016

Parameters	Amylose content	Gel consistency	Gelatinization temperature	Elongation ratio
Amylose content	1			
Gel consistency	-0.65*	1		
Gelatinization temperature	0.60	-0.99**	1	
Elongation ratio	0.73*	-0.95**	0.94**	1

*Significant difference at 5% level, **Significant difference at 1% level

4.2 Monsoon Rice Storage Experiment

Mean effect of storage containers and storage durations on grain quality and seed qualitiy of Manawthukha variety, monsoon season storage, 2017 are shown in Table 4.6 and 4.7.

4.2.1 1000 grain weight

The mean 1000 grain weight as affected by different storage conditions is shown in Table 4.6. The results showed that there were highly significant differences in 1000 grain weight among storage containers (Pr = 0.0002). Among the storage containers, air tight tin bin gave the highest thousand grain weight (20.33 g) followed by bamboo basket (19.95 g) and woven plastic bag (19.92 g). In bamboo basket and woven plastic bag, 1000 grain weight was not statistically different. It was also significantly different among storage durations (Pr < 0.0001) and decreased with storage durations. The highest 1000 grain weight was obtained from no storage (20.56 g) followed by two months storage (20.04 g) and the lowest value were obtained from four months storage (19.60 g). This result probably due to storage duration was synchronized with onset of dry season. Therefore, seed moisture lost during storage period because of hycroscopicity of rice grains (Chakraverty et al. 2003).

There was significant interaction between storage containers and storage durations (Pr = 0.04) (Figure 4.12). This result indicated that the changes of 1000 grain weight in storage containers were influenced by storage durations. In two months storage, 1000 grain weight significantly decreased in all types of storage containers than no storage (20.60 g). There were 20.0 g of 1000 grain weight in air tight tin bin, 19.40 g in bamboo basket and woven plastic bag respectively. After four months storage, 1000 grain weight significantly increased in all types of storage containers. In air tight tin bin, increased 1000 grain weight (20.40 g) was not significantly different from no storage, however, those of bamboo basket (19.90 g) and woven plastic bag (19.80 g) were significantly different from no storage. This might be due to 1000 grain weight greatly relied on its grain moisture content. Cesar et al. (2016) observed that fluctuation of moisture contents were observed during storage because of hygroscopic properties of the seeds and lack of control of temperature and relative humidity conditions lead to the occurrence of phenomena such as absorption and desorption.

Table 4.6 Mean effects of storage containers and storage durations of grain quality of Manawthukha variety, monsoon rice storage, 2017

Treatments	1000 grain weight (g)	Milling yield (%)	Head rice yield (%)
Container			
Air tight tin bin	20.33 a	52.99 a	34.57 b
Bamboo basket	19.95 b	55.45 ab	36.08 ab
Woven plastic bag	19.92 b	55.82 a	37.59 a
LSD $_{0.05}$	**0.20**	**2.63**	**2.07**
Duration (month)			
No storage	20.56 a	58.60 a	34.63 b
Two	20.04 b	56.52 a	38.94 a
Four	19.60 c	49.14 b	34.67 b
LSD $_{0.05}$	**0.20**	**2.63**	**2.07**
Pr ≥ F			
Container	0.0002	0.07	0.02
Duration	< 0.0001	< 0.0001	0.0002
Container x Duration	0.04	0.04	0.13
CV %	**1.16**	**5.71**	**6.81**

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

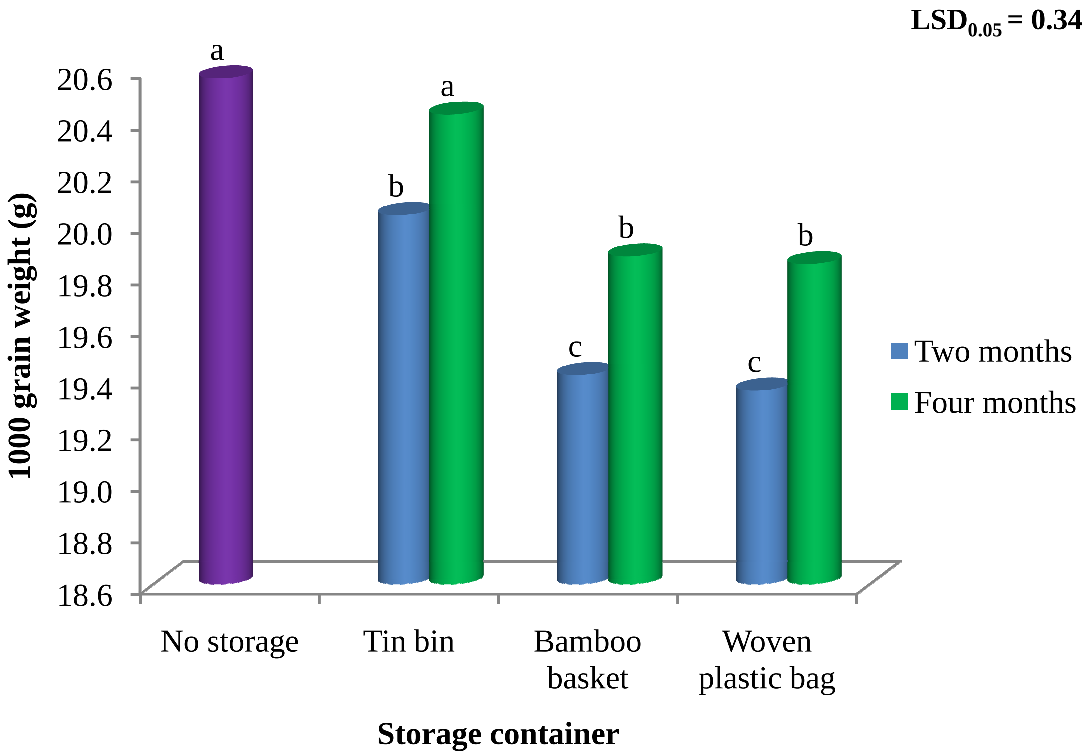

Figure 4.12 Effect of storage containers and storage durations on 1000 grain weight in monsoon rice storage, 2017

4.2.2 Milling yield

Milling yield of rice as affected by different storage conditions is shown in Table 4.6. The ANOVA result showed milling yield obtained from different storage containers was not statistically different (Pr = 0.07). By numerically, woven plastic bag gave the maximum milling yield (55.82%) followed by bamboo basket (55.45%) and air tight tin bin respectively (52.99%). This might be due to the same variety. Nevertheless, there were significant differences in storage durations (Pr < 0.0001). Milling yield decreased with storage durations. The maximum milling yield was resulted from no storage (58.60%) which was not significantly different from that of two months storage (56.82%). The lowest milling yield was resulted from four months storage (49.14%).

An interaction was found in milling yield between storage containers and storage durations (Pr = 0.04) is shown in Figure 4.13. These results indicated that the changes of milling yield with storage durations were governed by storage containers at 5% level. Milling yield of rice did not differ in two months storage in all types of storage containers and these were not statistically different from no storage (58.60%). These were 56.55% in air tight tin bin, 56.44% in bamboo basket and 56.58% in woven plastic bag respectively. However, after four months storage, milling yields were significantly lower in stored rice that in no storage. The lowest milling yield was found in air tight tin bin (43.83%) which was significantly lower than bamboo basket (51.32%) and woven plastic bag (52.28%), which were not significantly different.

4.2.3 Head rice yield

Head rice yield as affected by different storage containers and storage durations is shown in Table 4.6. In the ANOVA, significant differences of head rice yield were found in different types of storage containers (Pr = 0.02). This result might be due to different moisture equilibrium of seeds stored in different types of containers. Among the storage container, the highest head rice yield was observed in woven plastic bag (37.59%) followed by bamboo basket (36.08%). The minimum head rice yield was found in rice samples stored in air tight tin bin (34.57%) that was not significantly different from head rice yield of bamboo basket and woven plastic bag. Lower head rice yield resulted from air tight tin bin indicated that air tight storage could maintain the rice grains the same as at their fresh state, which was relatively soft in texture causing susceptibility to milling.

Moreover, head rice yields were significantly different among storage durations (Pr = 0.0002). Ankit (2014) stated that head rice yield and cooking properties were also affected ($p < 0.05$) by storage duration.

The highest head rice yield was found in two months storage (38.94%). The minimum head rice yields were observed in no storage (34.63%) and four months storage (34.67%), which were not significantly different with (34.63%). It indicates that two months storage might be the optimum time for milling.

The results showed no significant interaction between storage containers and storage durations (Pr = 0.13). The changes of head rice yield with storage durations were not influenced by storage containers. In all types of storage containers, head rice yield at two months storage were not significantly different, however significantly higher than that of no storage, and those of four months storage (Figure 4.14). Among the treatments, rice storage in air tight tin bin for four months resulted in minimum head rice yield (32%) whereas storage in woven plastic bag for two months gave the maximum head rice yield (39.91%) followed by storage in bamboo basket for two months (39.81%).

4.2.4 Moisture content

Means effect of moisture content of rice by different storage containers and storage durations is shown in Table 4.7. Initial grain moisture content before storage (no storage) was 12.46%. Moisture contents of stored rice significantly varied among the types of storage containers (Pr < 0.0001). Among the storage containers, air tight tin bin gave the highest grain moisture content (12.37%) and relatively stable as no storage (12.46%). This results might be due to the fact that tin bin was an air tight container, thus it could maintain its grain moisture at relatively stable. However, grain moisture contents significantly reduced in woven plastic bag and bamboo basket showing 11.14% and 10.85% respectively.

Furthermore, grain moisture content significantly decreased with increasing storage period (Pr <0.0001). There was (12.46%) of grain moisture content in no storage however grain moisture content decreased to (11.17%) after two months storage and (10.73%) after four months storage. This might be due to effect of environment because monsoon rice storage synchronized during dry season and also storage containers were kept in ambient conditions. It agreed with the statement of Dhaliwal et al. (1991) who stated that in all samples in no air tight storage bag (gunny bags) under ambient conditions, the moisture content of paddy decreased sharply within a month, and the moisture decreased further up to six months of storage, probably due to low temperature and dry weather.

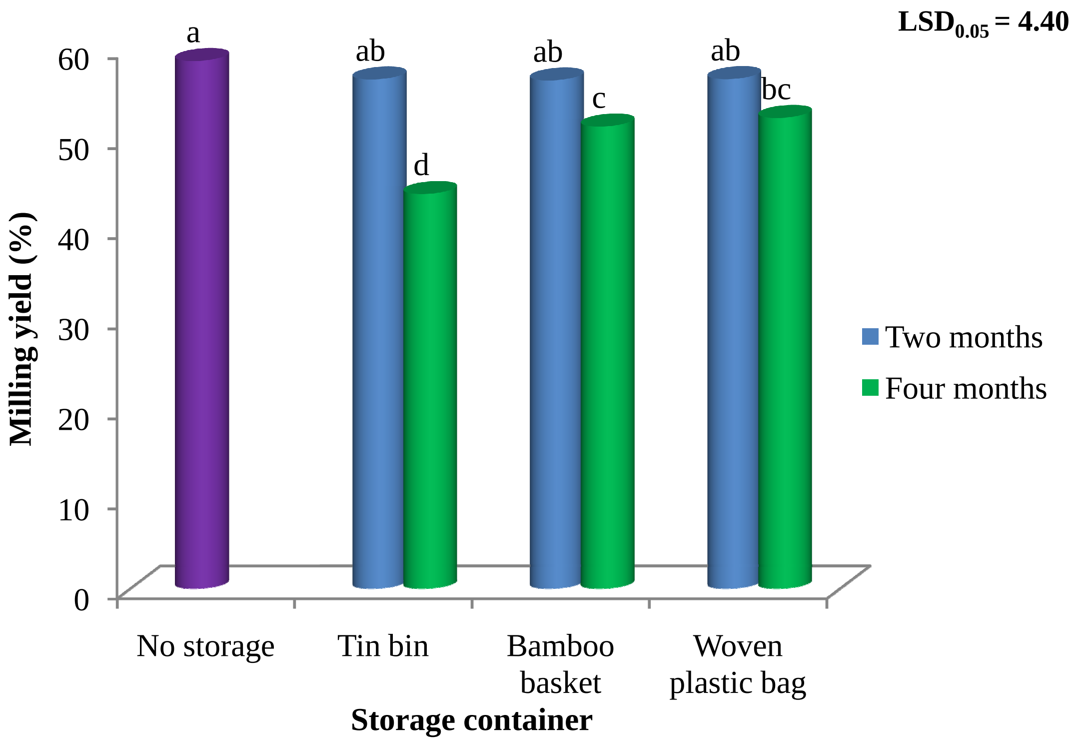

Figure 4.13 Effect of storage containers and storage durations on milling yield in monsoon rice storage, 2017

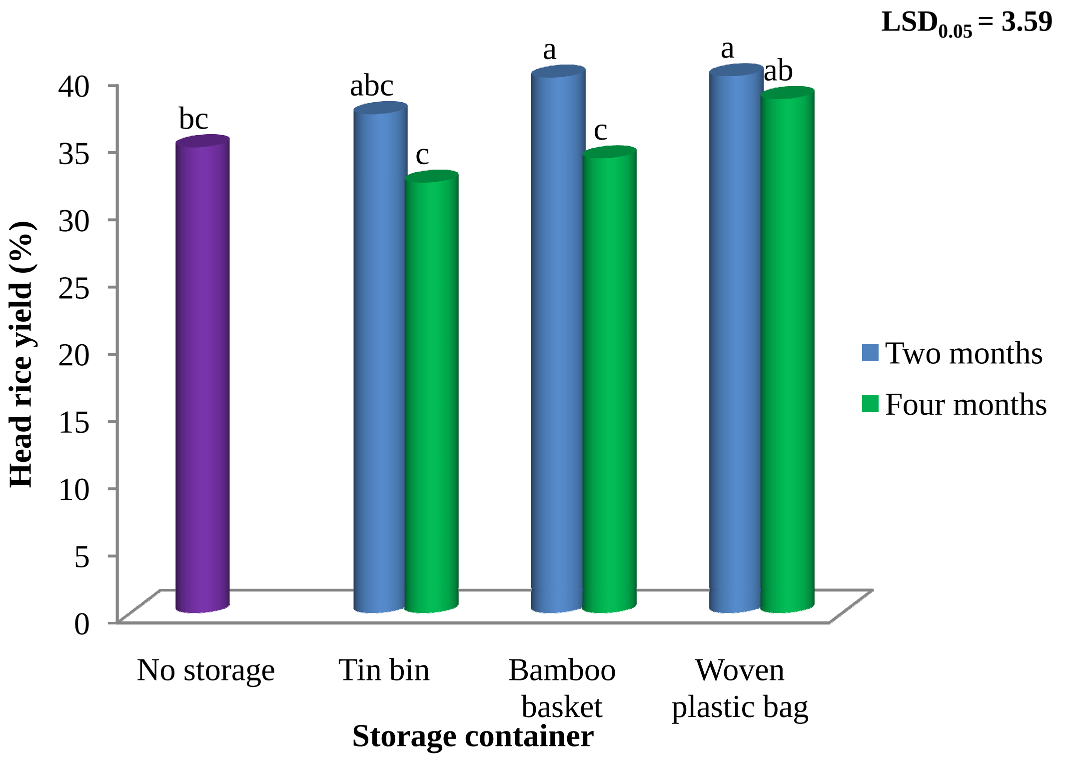

Figure 4.14 Effect of storage containers and storage durations on head rice yield in monsoon rice storage, 2017

Interaction effect between storage containers and storage durations was found in grain moisture content ($Pr < 0.0001$). This indicates that the changes of grain moisture content in storage containers were highly influenced by different storage durations. Among the storage containers, air tight tin bin maintained its moisture content almost stable along the storage period of four months at 12.29% and it did not statistically differ from grain moisture of no storage (12.46%) (Figure 4.15). However, moisture content of stored rice decreased along the period of storage in bamboo basket (10.30%), (9.79%) and in woven plastic bag (10.85%), (10.11%), at two months and four months of storage, respectively. This can be the fact that storage in bamboo basket and woven plastic bag could allow the gaseous exchange between the environment and containers, leading to change in grain moisture content to reach their equilibrium.

4.2.5 Germination percentage

Mean germination percentages as affected by the different storage conditions are presented in Table 4.7. There were no significant differences in types of storage containers ($Pr = 0.11$). Numerically, bamboo basket gave the maximum germination percentage (70.25%), followed by woven plastic bag (69.58%) and air tight tin bin (68.75%). This result might be due to good and stable germinability of Manawthukha variety.

On the other hand, germination percentage significantly varied in storage durations ($Pr < 0.0001$). Germination percentage significantly decreased in no storage (16.50%). However, the germination percentage of stored seeds was significantly higher than that of no storage both at two months and four months. There was no statistically difference between two months and four months 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 increased after each storage duration. Weir (1959) observed that seed dormancy in cultivated two rice varieties grown in Arkansas, was related to: time of harvest, moisture content at harvest, and drying method. Seed harvested at relatively high moisture levels and dried with natural, i.e. non-heated, air exhibited the greatest degree of dormancy.

No interaction was found between storage containers and storage durations ($Pr = 0.44$) in germination percentage of rice under current study. These results mean the changes of germination percentage with storage durations were not governed by types of storage durations. Germination percentage was significantly high after a period of storage

(Figure 4.16). This percentage indicated that beneficial effect of storage on germination. However, there was no significantly difference between two months and four months storage in all types of storage containers. This indicates that after dormancy breaking, Manawthukha rice could maintain its germination percentage higher than 90% until four months of storage even in different storage containers. Germination percentage were (94.00%), (95.75%) in air tight tin bin, (97.25%), (97.00%) in bamboo basket and (96.25%) in woven plastic bag respectively.

4.2.6 Germination index

The differences of germination index as affected by different storage containers and storage durations are shown in Table 4.7. There was no statistically difference among storage containers (Pr = 0.12). Numerically, the maximum germination index was obtained from bamboo basket (18.93) followed by woven plastic bag (18.63) and air tight tin bin (17.54) respectively. In contrast, Rosario et al. (2017) found that germination speed (germination index) was significantly different in the different storage materials on the fourth month of storage. Our results were not in agreement with their finding. That may be due to the combined effect of other factors, such as storage duration, storage environment, and types of storage containers.

Germination index was significantly affected by storage durations (Pr < 0.0001). It significantly increased with increase in storage durations. Germination index was 2.80 in no storage while 18.74 and 33.35 at two months and four months storage respectively. Variation in germination index was regarded mainly as the consequence of variation in germination percentage in all tested treatments.

There was no interaction effect on germination index between storage containers and storage durations (Pr = 0.50). Germination index significantly increased in all types of storage containers after four months of storage (Figure 4.17). There was no statistically difference among types of storage containers (18.02) at two months storage. After four months storage, germination index again significantly increased in all storage containers. The maximum value was obtained from bamboo basket (34.65) which was not significantly different from woven plastic bag (34.21) that was similar with air tight tin bin (31.79).

4.2.7 Seedling vigor index

The result of seedling vigor index as affected by different storage containers and storage periods is showed in Table 4.7. Storage containers did not affected on seedling vigor index (Pr = 0.11). This might be due to the fact that Manawthukha variety has good viability even in different storage containers. Among the storage containers, woven plastic bag gave the maximum seedling vigor index (8207.40) followed by bamboo basket (8039.10) and they were not significantly different each other. The minimum seedling vigor index was observed in air tight tin bin (7712.80) which did not significantly differ from bamboo basket.

However, seedling vigor index were significantly different among storage durations (Pr < 0.0001). It can be seen that seedling vigor index were increasing with storage duration, showing 10467 at two months storage and 12075 at four months storage compared to no storage (1417). Seedling vigor index of rice at three storage durations were significantly different each other.

The result of Figure 4.18 indicates that there was no interaction in seedling vigor index between storage containers and storage durations (Pr = 0.45). The changes in seedling vigor index with storage durations were not influenced by different storage containers. At two months of storage time, seedling vigor index significantly increased in all types of storage containers. However, there was no statistically different among storage containers. The results showed a significant increase in seedling vigor index at four months storage compared to two months storage. In four months storage, the highest seedling vigor index was obtained from woven plastic bag (12057). The minimum seedling vigor index was obtained from bamboo basket (12024) and air tight tin bin (11605). They were not significantly different each other, however they were significantly lower than that of woven plastic bag. Variation in seedling vigor index is related to the difference in their germination percentage and growths such as seedling shoot and root length. Under the storage for four months duration, the type of storage container, woven plastic bag was assumed as appropriate than the remaining two other storage containers, air tight tin bin and bamboo basket.

Table 4.7 Mean effects of storage containers and storage durations on seed quality of Manawthukha rice variety, monsoon rice storage, 2017

Treatments	Moisture content (%)	Germination percentage (%)	Germination index	Seedling vigor index
Container				
Air tight tin bin	12.37 a	68.75 b	17.54	7712.80 b
Bamboo basket	10.85 c	70.25 a	18.93	8039.10 ab
Woven plastic bag	11.14 b	69.58 ab	18.63	8207.40 a
LSD $_{0.05}$	**0.14**	**1.42**	**1.40**	**472.46**
Duration (month)				
No storage	12.46 a	16.50 b	2.80 c	1417.00 c
Two	11.17 b	95.75 a	18.74 b	10467.00 b
Four	10.73 c	96.33 a	33.55 a	12075.00 a
LSD $_{0.05}$	**0.14**	**1.42**	**1.40**	**472.46**
Pr ≥ F				
Container	< 0.0001	0.11	0.12	0.11
Duration	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Container x Duration	< 0.0001	0.44	0.50	0.45
CV %	**1.41**	**2.43**	**9.06**	**7.02**

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

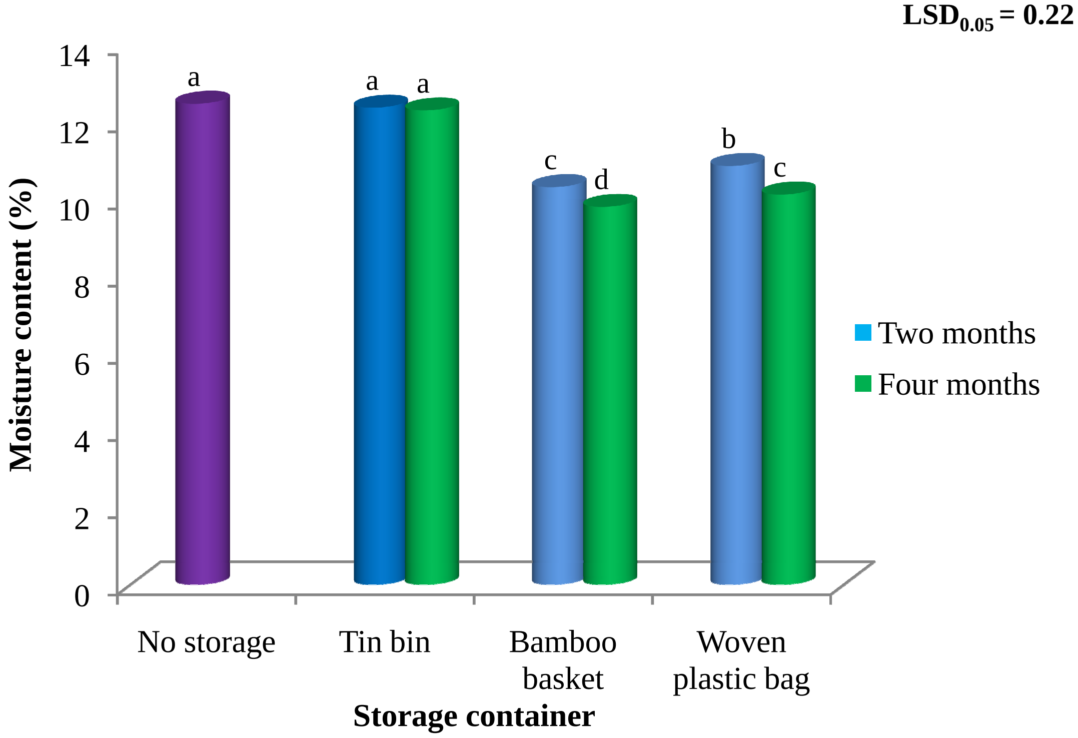

Figure 4.15 Effect of storage containers and storage durations on moisture content in monsoon rice storage, 2017

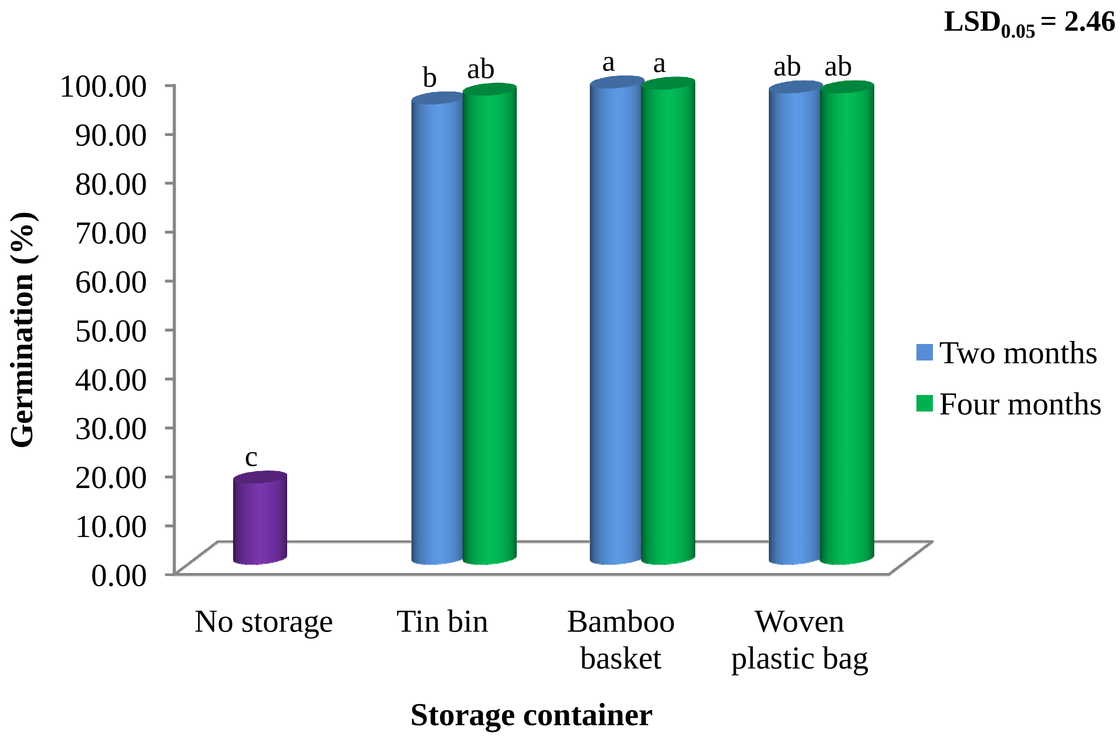

Figure 4.16 Effect of storage containers and storage durations on germination percentage in monsoon rice storage, 2017

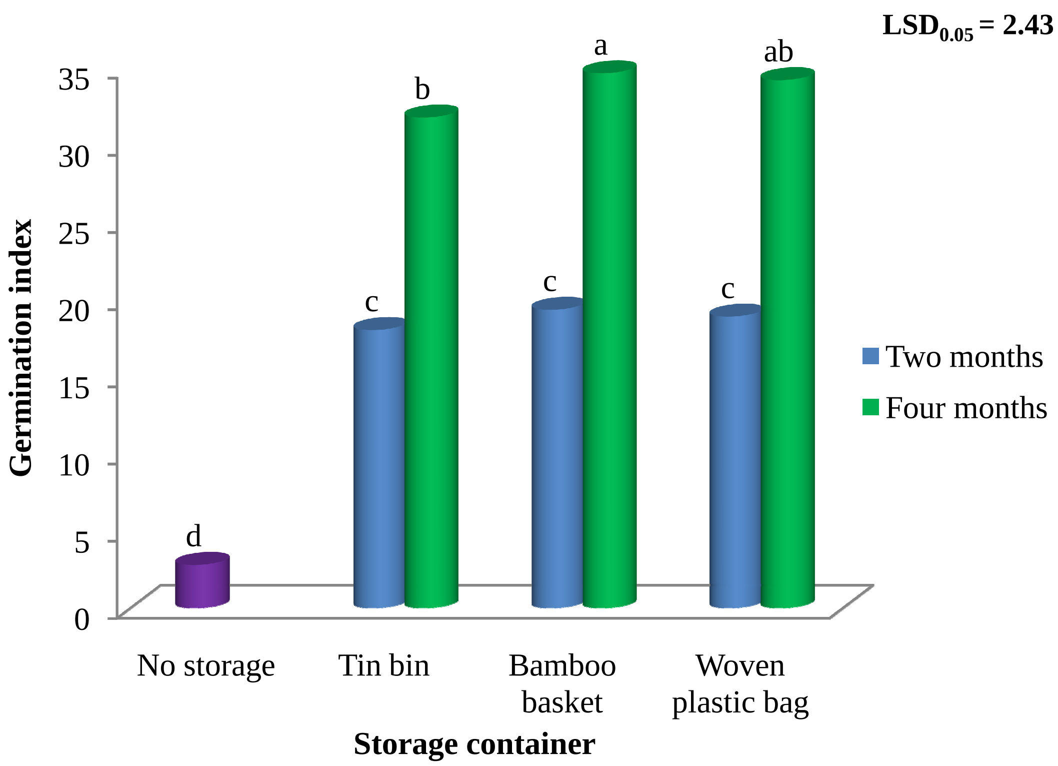

Figure 4.17 Effect of storage containers and storage durations on germination index in monsoon rice storage, 2017

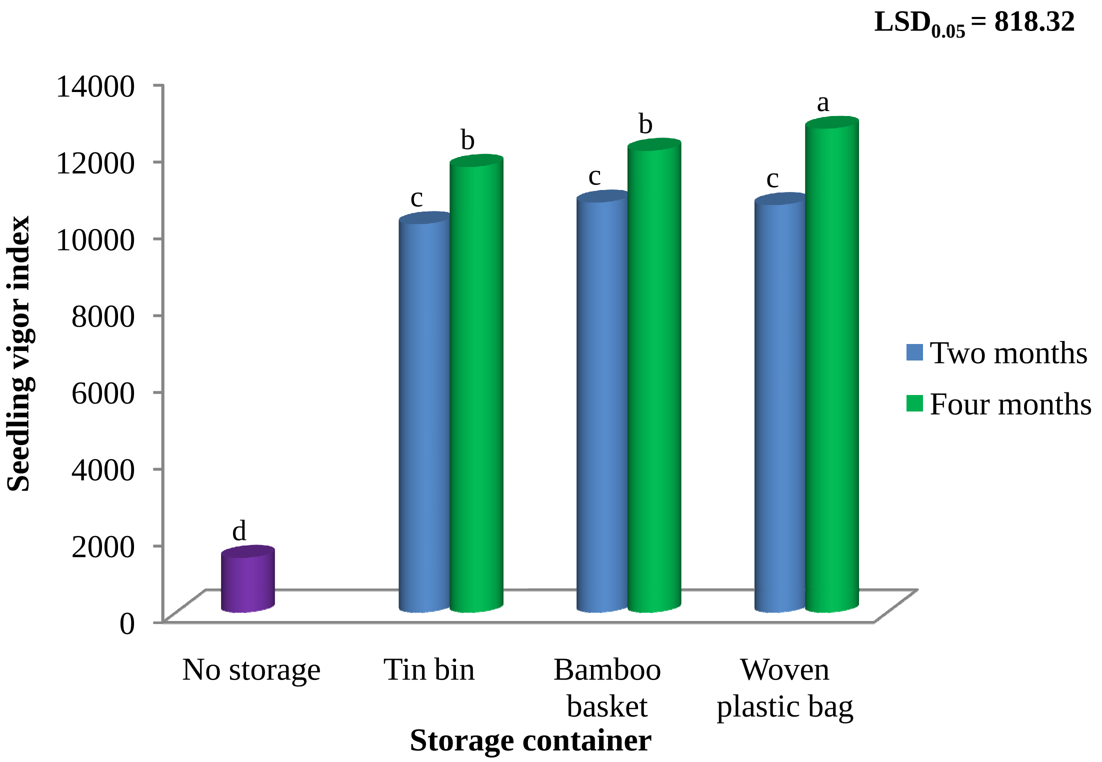

Figure 4.18 Effect of storage containers and storage durations on seedling vigor index in monsoon rice storage, 2017

4.2.8 Amylose content

The amylose content of rice grains stored in different storage containers for different storage durations is presented in Figure 4.19. The mean value of amylose content before storage was 31.60%. According to Williams et al. (1985), this value indicates high level of amylose content. Amylose content of rice increased with storage durations in all types of storage containers. Increasing rate was higher in four months storage than in two months storage. This might be due to the fact that enzymatic activity of fresh rice is very active, therefore amylose content can be well breakdown. However, enzymatic activity gradually decreased with storage. Therefore, amylose content of stored rice is slightly higher than that of fresh rice.

In two months storage, amylose content of stored rice were 31.80%, 31.90% and 32.30% in air tight tin bin, bamboo basket and woven plastic bag, respectively. Among the storage containers, woven plastic bag gave the maximum amylose content followed by bamboo basket and air tight tin bin. At four months storage, amylose contents of stored rice increased in a trend similar as two months storage among the containers. The maximum amylose content was observed in woven plastic bag (32.50%) followed by bamboo basket (32.30%) and air tight tin bin (32.0%).

4.2.9 Gel consistency

The effect of different storage containers and storage durations on gel consistency of rice is shown in Figure 4.20. After two months storage gel consistency of stored rice was sharply lower than no storage. The mean value of gel consistency in no storage was 43 mm. This value is consistent in intermediate level (Cagampang et al. 1973). However, gel consistency decreased to hard level after storage. Although starch of fresh rice is formed in a solution state, these starch has been changed into granules during storage. Therefore, gel of starch is harder in stored rice than fresh rice. However, gel consistency of stored rice was not significantly different among all the treatments. A slight variation was found among the different types of containers, different durations of storage and their combined effect under four months in this study.

Among the storage containers, woven plastic bag gave the maximum gel consistency (31.50 mm) followed by air tight tin bin (28.50 mm) and bamboo basket (26.50 mm). However, there was a slight change between two months and four months storage. The maximum gel consistency was found in air tight tin bin (29.00 mm) followed by bamboo basket and woven plastic bag (28.00 mm) respectively. Kanlayakrit and Maweang (2013) found that the gel formed by aged rice flours were harder than those of fresh rice flours and gave firmer texture of flours. However, gel consistency of the rice decreased after four months storage and tended to be stable even storing at room temperature and warehouse temperature.

4.2.10 Gelatinization temperature

Effect of storage containers and storage durations on gelatinization temperature of rice is shown in Figure 4.21. Gelatinization temperature of sample rice before storage was (74-75°C) including in high/intermediate level (Juliano 1971). There was a prominent increase to high level after two months storage in all storage containers. This might be due to physicochemical changes of rice grains occurred during storage. Therefore, gelatinization temperature of stored rice is usually higher than that of fresh rice. This means that cooking time of stored rice is longer than that of fresh rice. Numerically similar value of gelatinization temperature (80°C) was found among storage containers in two months storage.

In addition, the gelatinization temperature was almost remained unchanged between two months and four months storage in all storage containers (80°C). Increased gelatinization temperature of stored rice during storage might be due to effect of aging. 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.

4.2.11 Elongation ratio

Mean values of elongation ratio of rice as affected by different storage containers and storage durations is shown in Figure 4.22. Elongation ratio of rice after storage was slightly higher than no storage (1.5) after two months storage. It was a few variations in elongation ratio among the storage containers. Woven plastic bag gave the maximum elongation ratio (1.7) followed by air tight tin bin (1.6) and bamboo basket (1.6). It was almost similar between air tight tin bin and bamboo basket at two month storage. Elongation ratio was higher at four months storage than two months storage.

The maximum elongation ratio was resulted from bamboo basket and woven plastic bag (1.9) each followed by air tight tin bin (1.7). It was almost the same between bamboo basket and woven plastic bag. Higher elongation ratio of stored rice might be due to effect of aging process during storage. It has been found that aged rice is more capable of absorbing water as well as its size is accordingly increased compared to the fresh one (Howell and Cogburn 2004). Haneefa (2012) reported that elongation of cooked rice increased during ageing process as a result of change in starch granule leading to greater resistance of the grain to disintegration during cooking.

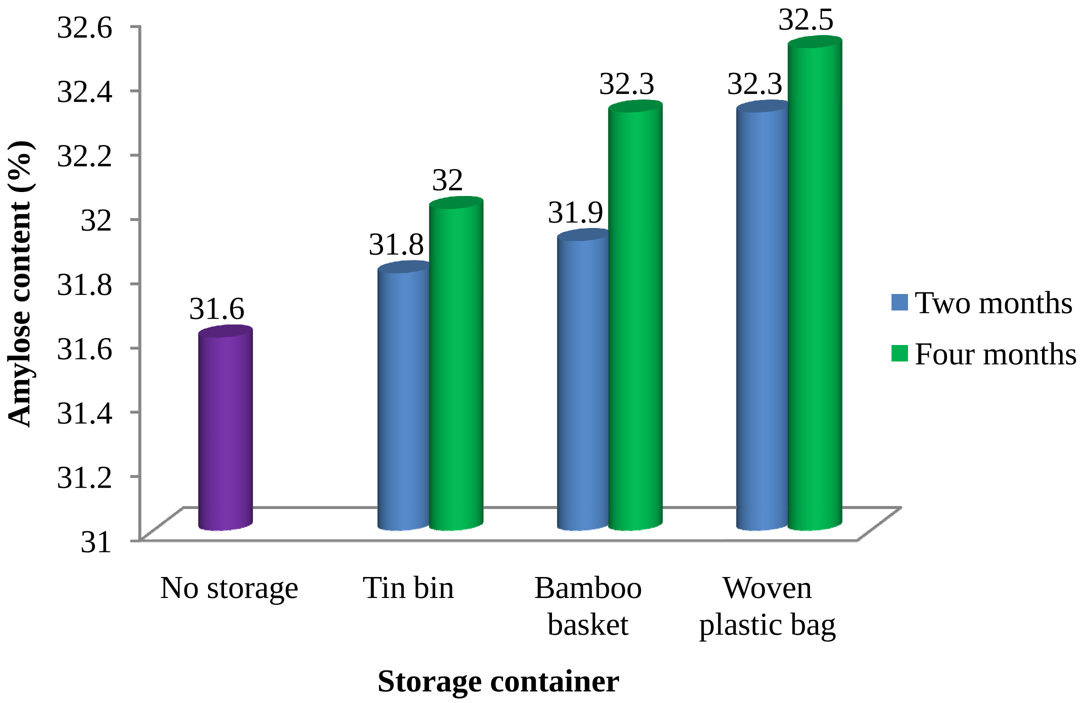

Figure 4.19 Mean values of amylose content as affected by storage containers and storage durations in monsoon rice storage, 2017

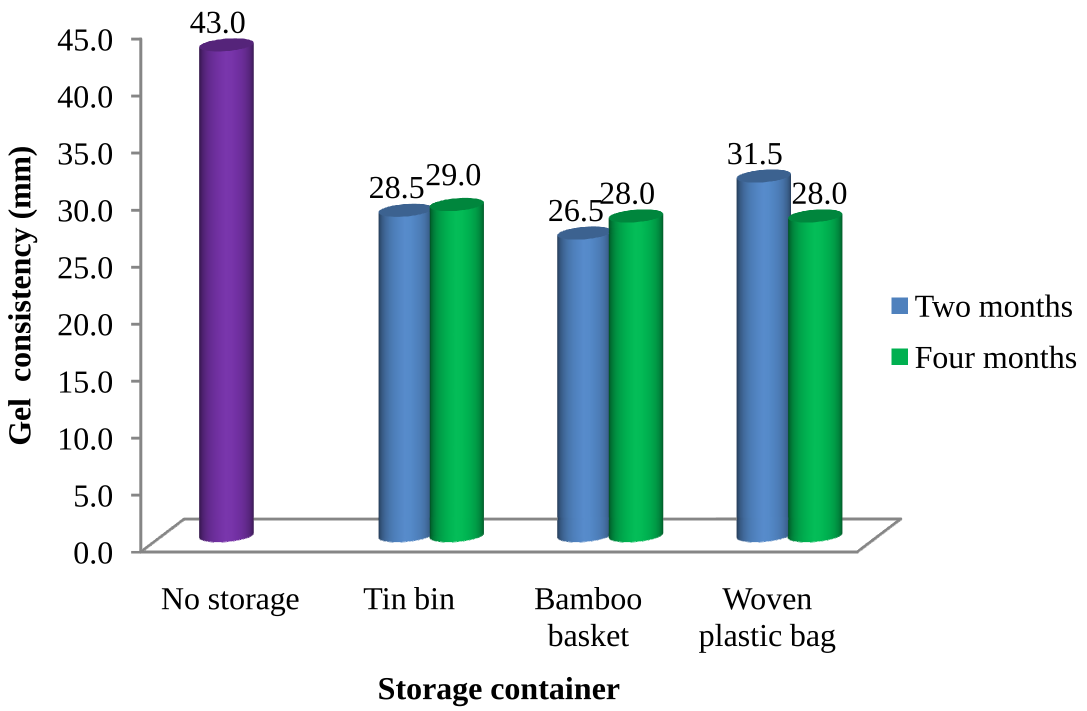

Figure 4.20 Mean values of gel consistency as affected by storage containers and storage durations in monsoon rice storage, 2017

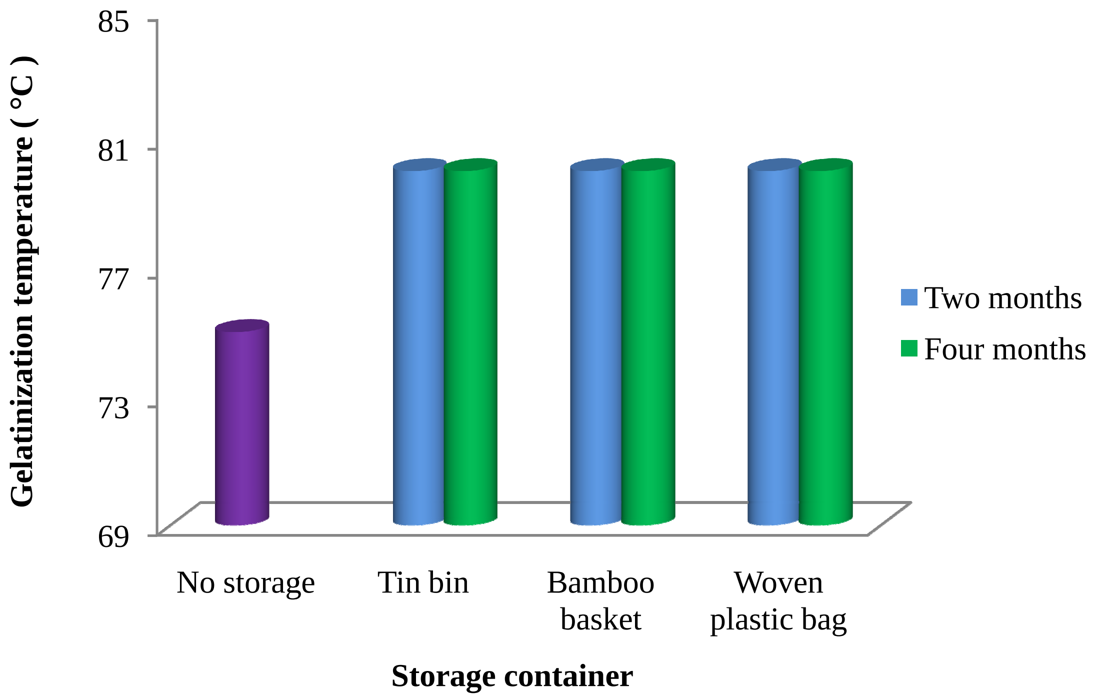

Figure 4.21 Mean values of gelatinization temperature as affected by storage containers and storage durations in monsoon rice storage, 2017

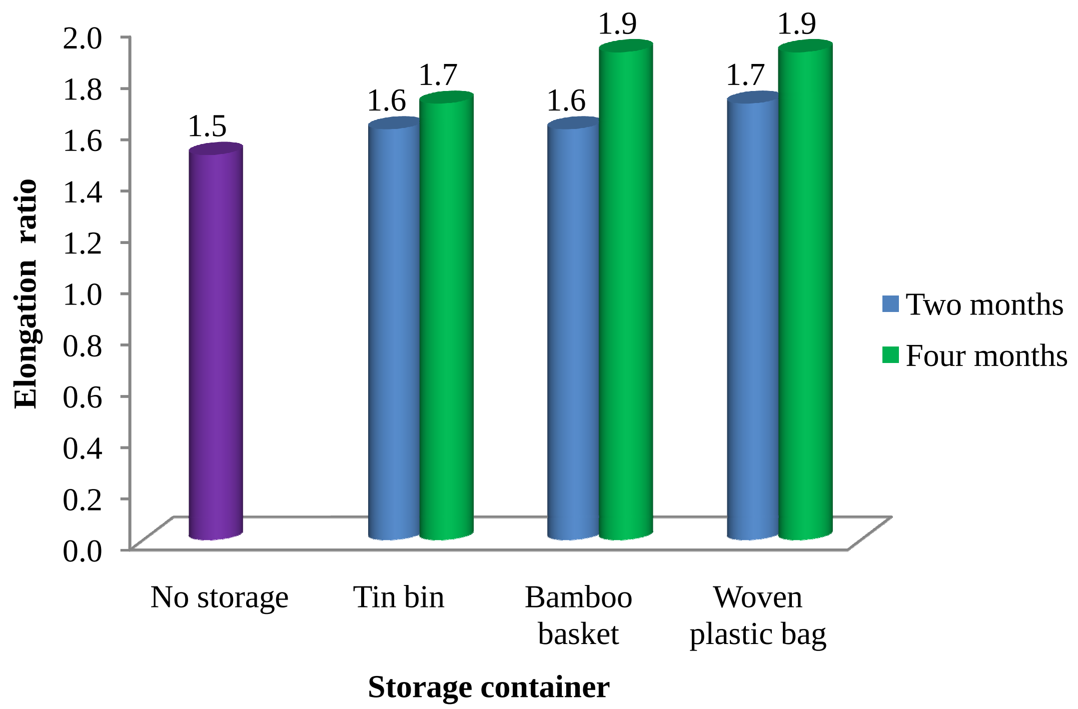

Figure 4.22 Mean values of elongation ratio as affected by storage containers and storage durations in monsoon rice storage, 2017

4.2.12 Correlation coefficient among grain qualities of Manawthukha rice variety as affected by different storage containers and storage durations in monsoon rice storage, 2017

Correlation coefficient among grain quality parameters as affected by different storage containers and storage durations in monsoon rice storage is shown in Table 4.8. Moisture content was significantly and positively correlated with 1000 grain weight at 5% level. Although it was not significant, head rice yield had a negative correlation grain moisture content and positive correlation with milling yield. Khatun et al. (2003) reported that milling yield was positively correlated with head rice yield. Baishali et al. (2016) also found that milling percent shows a similar positive correlation with head rice recovery.

4.2.13 Correlation coefficient among seed qualities of Manawthukha rice variety as affected by different storage containers and storage durations in monsoon rice storage, 2017

Correlation coefficient among seed quality parameters as affected by different storage containers and storage durations in monsoon rice storage is shown in Table 4.9. Moisture content was significantly and negatively correlated with germination index and seedling vigor index at 5% level and also negatively correlated with germination percentage although it was not significant. Germination percentage, germination index and seedling vigor index were highly and positively correlated with germination percentage each other at 1% level. Germination index was positively correlated with seedling vigor index at 1% level.

4.2.14 Correlation coefficient among physicochemical properties of Manawthukha rice variety as affected by different storage containers and storage durations in monsoon rice storage, 2017

Correlation coefficient among physicochemical properties of Manawthukha rice variety as affected by different storage containers and storage durations in monsoon rice storage is shown in Table 4.10. Amylose content was positively correlated with gelatinization temperature and elongation ratio at 1% level, however, it was negatively correlated with gel consistency at 5% level. Gel consistency was negatively correlated with gelatinization temperature at 5% level and elongation ratio at 1% level, respectively. Gelatinization temperature showed a positive correlation with elongation ratio at 5% level. However, Lum (2017) found that gelatinization temperature (cooking time) of the rice varieties showed a strong negative correlation with elongation ratio (r = -0.990, p≤0.05). Baishali et al. (2016) reported a significant and positive correlation between amylose content and gel consistency. Khatun et al. (2003) observed that amylose content was highly significant and negative correlation between gel consistency and gelatinization temperature while positive association with elongation ratio. In addition, gelatinization temperature was highly significant positive association with gel consistency while negative association with elongation ratio.

Table 4.8 Correlation among grain quality parameters as affected by storage containers and storage durations in monsoon rice storage, 2017

Parameters	Moisture content	1000 grain weight	Milling yield	Head rice yield
Moisture content	1			
1000 grain weight	0.79*	1		
Milling yield	0.22	0.04	1	
Head rice yield	-0.49	-0.82**	0.42	1

*Significant difference at 5% level, **Significant difference at 1% level

Table 4.9 Correlation among seed quality parameters as affected by storage containers and storage durations, monsoon rice storage, 2017

Parameters	Moisture content	Germination percentage	Germination index	Seedling vigor index
Moisture content	1			
Germination percentage	-0.66	1		
Germination index	-0.69*	0.88**	1	
Seedling vigor index	-0.70*	0.99**	0.94**	1

*Significant difference at 5% level, **Significant difference at 1% level

Table 4.10 Correlation among physicochemical properties as affected by storage containers and storage durations in monsoon rice storage, 2017

Parameters	Amylose content	Gel consistency	Gelatinization temperature	Elongation ratio
Amylose content	1			
Gel consistency	-0.73*	1		
Gelatinization temperature	0.94**	-0.72*	1	
Elongation ratio	0.77**	-0.98**	0.73*	1

*Significant difference at 5% level, **Significant difference at 1% level

CHAPTER V
SUMMARY AND CONCLUSION

The present study emphasized the effect of different storage containers and storage durations on grain and seed quality of Manawthukha rice in summer rice storage and monsoon rice storage. Manawthukha rice is one of the popular rice varieties in Myanmar, which is long-grain rice belonging to high amylose variety. It is short-lived Letywezin variety. Grain appearance is translucent. Yield and milling recovery are good. Eating quality is fairly good, however slightly hard. It was widely grown in Myanmar and resistant to Rice Blast disease.

Manawthukha rice is commercially and widely grown in most of rice growing regions of Myanmar. Myanmar rice growers commonly use their own seeds from last growing season by themselves. To understand the effect of different storage conditions, on rice quality, current study was conducted at the laboratory of Department of Agronomy, Yezin Agricultural University, Nay Pyi Taw from December 2016 to May 2017. Based on the results of this study, head rice yield and 1000 grain weight were significantly different as a result of significant variation in moisture content of stored seed by the response to types of storage container and storage duration. Milling yield, germination percentage, germination index and seedling vigor index 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 increased, and gel consistency decreased with increasing storage duration in all treatments. However, the rates of change 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.

Germination percentage, germination index and seedling vigor index showed a highly positive correlation each other. Elongation ratio was positively correlated with amylose content, but negatively correlated with gel consistency. There was a highly negative correlation between amylose content and gel consistency.

Types of storage container and storage duration significantly influenced on all characters of grain quality, seed quality and physicochemical properties of rice grain for both summer and monsoon rice storage. Variation in rice quality was mainly due to the effect of storage duration rather than storage container for a period of four months. After storage, amylose content, gelatinization temperature, gel consistency and elongation ratio decreased in all types of storage containers and storage durations. Air tight tin bin could maintain grain moisture relatively stable throughout the storage period than other containers under four months storage.

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.

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