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Effective and economic storage of wheat seed in straw-clay bin

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Abstract

The majority of farmers in Sindh province of Pakistan store wheat seed in traditional storage structures. These structures usually increase seed moisture and temperature of storage up to the levels that favor the proliferation of insects and fungi and results in seed deterioration. Considering the seed storage problem, the present study was performed. Straw-clay bins retain low moisture conditions for extended storage duration better than conventional bulk covered store. Seed stored in bulk covered store suffered severe deterioration caused by fungi, while straw-clay bins protected seed from these losses. Wheat seed stored for 12 months in straw-clay bins maintained better seed germination percentage, test weight, protein content and ash/mineral content than seed stored in bulk covered store. There was a minimum loss of quality of wheat in straw-clay bin as compare to bulk covered store. Hence, the adoption of the straw-clay bin must be encouraged in the developing countries to save their seeds and goods to reduce the losses as well as raise the food security, poverty alleviation and national economy.

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Introduction

Grain storage plays a vital role in food security which helps to sustain sufficient food demands between two harvests. It also helps in maintaining the cost of the grains by protecting the produce during its peak season and supplies the grains back to the market in good quality during off season (Proctor, 1994). Wheat is one of the most important crops in the world and represents an essential source of carbohydrates, protein, minerals and fibers for human nutrition. Wheat is widely grown on an area of about 8693000 hectares with the total production of about 24.2 million tons in Pakistan. The average yield of wheat in Pakistan is around 2787 kg ha^{-1}, contributing 2.2% to the GDP (GOP, 2013). It is harvested in a short period of time, but is later processed and consumed throughout the year.

The post-harvest loss of wheat grains has been observed highest during storage (Magan, 2003). In spite of different control methods, around 9.3 to 42% of wheat production is exhausted due to attack of different pests, insects and weeds (Dhaliwal and Arora, 2001). Generally in Pakistan, wheat seeds are stored at farmer level in traditional storage structures such as jute bags, earthen bins, room stores, bulk covered and metal bins under adverse conditions of temperature and moisture. (Alagusundaram *et al.*, 1990; Sorour and Uchino, 2004). The absence of proper storage structures for grain keeping and lack of storage organization frequently force the agriculturists to sell their produce quickly after harvest to keep away from misfortunes. Therefore, farmers get low market prices for any excess grain produce (Kimenju *et al.*, 2009). Seed moisture and temperature also influence on biochemical changes (Reed *et al.*, 2007) beside, these variables have a direct effect on the quality of stored grains which leads to the growth and multiplication of insects and molds (White *et al.*, 1982; Rajarammanna *et al.*, 2010). Fungal infection in stored grains has impact on the quality of grains which leads to the loss of nutritional quality as well as decreases germination rate. Therefore, the appearance of mould growth and its off-odour is considered as an indication of spoilage as well as helps to predict the length of stored grains (Mills and Woods, 1994). Molds growth appears in the grains stored at higher level of moisture irrespective of storage temperature (Sathya *et al.*, 2008).

Fluctuations in temperature, humidity and prolonged storage results in considerable nutrients loss (Shah *et al.*, 2002). Safe storage of grains at the homestead level is vital at expected dampness and temperatures during storage. This would offer data to the farmers for supporting them in scheduling different post-harvest treatments before the deterioration of grain quality (Sathya *et al.*, 2009) as it is specifically related with poverty reduction, food security, income generation and flourishing of the agriculturists. Therefore, it is essential that proper and low cost storage innovations are promptly exhibited to agriculturists to securely store and keep up quality of their produce (Thamaga-Chitja *et al.*, 2004). Moreover, the stable supply of grains during off season may also provide the rural people with better income source and food security (Tefera, 2012). Thus, the objective of the current research work is to evaluate the efficiency of the straw-clay bins against the conventionally used bulk covered store on quality of the stored wheat.

Materials and Methods

Study area

The experiment was performed from 1st July 2013 to 1st July 2014 at Latif experimental farm of Sindh Agriculture University Tandojam, Pakistan, located at 25° 25'40"(N), 68° 31'40"(E), 19.5 m above sea level in southern agro-ecological zone of Sindh province (Fig. 4). As per the meteorological observatory of Drainage Research Center Tandojam, the atmosphere of Tandojam is hot and dry with normal yearly precipitation of 88.6 mm. The greatest normal temperature in summer could go as higher as 40 °c that happens in the month of May and least mean temperature of 11 °c happens in January. The relative humidity is most elevated (84%) in the month of August while least (58%) in the month of April.

Seed storage methods

Straw-clay bin: For this study, straw-clay bin of 2500 kg capacity was constructed from rice-straw and clay materials (Fig. 1 & 2). Exclusively the mud has a low elasticity; However it can be expanded when straw and earth are consolidated together. In order to construct straw-clay composite, the clay was soaked in water at the ratio of 2:1 (clay: water) for 24 hours and mixed manually until a uniform slurry is formed. The straw bundle was spread out flat and soaked with clay slurry, twisted together and removed excess mud. Foundation of the bin was constructed from burnt clay bricks and cement mortar beyond the level of ground to provide protection of stored wheat from soil/surface water. A floor was fabricated from a layer of bitumen and polythene sheet between two layers of cement concrete to prevent damp rising from the soil. Wall of the bin was constructed from horizontal layers of straw-clay bundles. In order to monitor the stored seed three channels of PVC pipe with cover were inserted across the bin wall at top, middle and bottom position. Inlet for seed was provided at the top of bin wall while an outlet provided at the bottom of wall. A conical roof was constructed with bamboo rafters fixed at 45^o slopes over the wooden ring beam, covered with straw clay bundles and over hanged from the wall to protect the wall from rain.

Bulk covered store: In this method farmers simply dump the seed on the ground and cover it utilizing straw and mud plaster to avoid deterioration of seed. For the most part the ground of this structure is additionally secured with mud and straw layer. Trench is dug around the structure to empty rain water (Fig. 3).

Wheat seed

The newly harvested wheat seed was taken from the Research centre of Sindh Agriculture University Tandojam and cleaned manually (stones, straw and dirt was removed). The seed quality assessment characteristics such as moisture content, test weight, fungal incidence, germination ability, protein and ash/mineral content were determined upon arrival of the seed. The storage structures were then loaded with wheat seed completely.

Seed sampling

Seed sampling was done from bottom, middle and top of all stores by using sampling probe at every 3 months interval (3, 6, 9 and 12 months). The seed samples were then mixed thoroughly to obtain a compound sample. The analysis of these samples for quality assessment characteristics was performed at the laboratory of Pakistan Council of Scientific and Industrial Research (PCSIR), Hyderabad. Moreover, relative humidity and ambient temperature of the study area were noted monthly for whole storage duration using dry and wet bulb thermometers.

Determination of seed quality parameters

Seed moisture content (%) was calculated according to the procedure of AACC (2000) method No. 44-15A. Germination ability (%) was calculated from 100 randomly selected wheat seeds from each store, placed on double layer of filter paper in petri dishes, moistened with distilled water and placed in germinator at 25 °C for 5-7 days (ISTA 1996). The examination for fungi in the stored wheat was carried out by seed plating technique. The percentage of seeds infected was calculated by shaking about 100 kernels for 1 min in 2% sodium hypochlorite (NaOCl) solution, washing twice with sterile refined water, and plating on malt agar (MSAT) containing 6% sodium chloride in addition to Tergitol (Stroshine *et al.*, 1984). After incubation for 5-7 days at room temperature (25-27 °C), the fungi growing in each grain were recognized and the percentage of fungal incidence was noted. The test weight (Kg/hl) was determined following the procedure given in AACC (2000) method No.55-10 for each seed sample in which one litter vessel was filled and leveled with wheat seeds and weighed on digital balance. The nitrogen content in each one seed sample was assessed by utilizing Kjeldahl's strategy as indicated by the methodology explained in AACC (2000) system No. 46-10. The protein (%) was calculated by multiplying nitrogen percent with a factor 5.7. The ash/mineral (%) in each one seed example was resolved as an inorganic matter by following the technique given in AACC (2000) strategy No. 08-01. Oven dried 5 g sample was ignited in a muffle furnace at a temperature of 550-600 °C for 5-6 hours or till greyish ash formed.

Data analysis

Analysis of variance (ANOVA) was carried out using two factorial model considering storage method kind (straw/clay bin and bulk covered store) and storage length (3, 6, 9 & 12 months) as fixed effect factors and replications as random effect factors. Means comparison was made using least significant difference at 0.05.

Results

Variation in ambient temperature and relative humidity of experimental site

A decreasing trend was observed in ambient temperature and relative humidity from July, 2013 to January, 2014 reached to a lowest value of 23.6 °C and 62%, respectively. From January, 2014 both ambient temperature and relative humidity increased gradually to the highest value of 40.3 °C and 72%, respectively (Figure 1).

Initial data of wheat seed at loading

The freshly harvested wheat seed was dry (14.6% average moisture), had high germination ability (96% average), the average fungal incidence was 1.6%, the average test weight was 74 kg/hL, and had high protein (12.46% average) and ash/mineral contents (2.04% average).

Table 1. Means of seed quality characteristics evaluated in the present study based on storage method and storage length.

Factors	Characteristics					
	Moisture content (%)	Fungi (%)	Test weight (kg/hL)	Germination (%)	Protein content (%)	Ash/ mineral content (%)
Storage method						
Straw-clay bin	12.91b	5.25b	73.06a	88.00a	12.20a	1.877a
Bulk covered store	13.94a	12.0a	71.25b	73.75b	10.50b	1.780b
LSD (0.05)	0.0073	0.7307	0.0053	0.4680	0.0081	0.0045
Storage duration						
3 months	14.12a	5.00d	73.63a	93.50a	12.08a	1.970a
6 months	12.88d	7.00c	73.33b	87.50b	11.82b	1.935b
9 months	13.13c	9.00b	71.80c	76.00c	11.18c	1.745c
12 months	13.57b	13.5a	69.86d	66.50d	10.32d	1.665d
LSD (0.05)	0.0103	1.0334	0.0076	0.6619	0.0115	0.0064

Means followed by the same letter in each column are not different significantly according to least significant difference (LSD) at 5% probability level.

Impact of storage methods

Storage methods showed significant effect on seed moisture, test weight, fungal incidence, germination ability, protein content and ash/mineral content (Table 1). The evaluation of storage methods exhibited that test weight (73.06 kg/hL), germination ability (88.0%), protein content (12.2%) and ash/mineral content (1.877%) were significantly higher in seed samples taken from straw-clay bin than in bulk covered store. The seed moisture (13.94%) and fungal incidence (12.0%) were significantly higher in bulk covered store as compare to straw-clay bin.

Impact of storage length

Storage length also showed a significant effect on seed moisture, test weight, fungal incidence, germination ability, protein percentage and ash/mineral percentage (Table 1). The germination ability, test weight, protein content and ash/mineral content decreased throughout the storage period to get the lowest values of 66.5%, 69.86 kg/hL, 10.32% and 1.665%, respectively were found at the end of storage (12 month). An increase in fungal incidence was observed with the storage period and the highest value of 13.5% was detected at 12 months. Seed moisture content followed the pattern of the relative humidity throughout the storage duration. It decreased during the first 6 months and then gradually increased till 12 months.

Table 2. Moisture, fungi, test weight, germination ability, protein and ash of wheat seed under interactive effect of storage method and storage length.

Storage method	Storage duration	Moisture content (%)	Fungi (%)	Test weight (kg/hL)	Germination (%)	Protein content (%)	Ash content (%)
Straw-clay bin	3 month	14.46b	2.00g	73.66a	94.0a	12.45a	1.98a
	6 month	12.18h	4.00f	73.36c	91.0c	12.38b	1.94c
	9 month	12.42g	6.00e	72.90e	86.0d	12.19c	1.83e
	12 month	12.58f	9.00cd	72.32f	81.0f	11.78d	1.76f
Bulk covered store	3 month	13.78d	8.00d	73.60b	93.0b	11.71e	1.96b
	6 month	13.58e	10.0c	73.30d	84.0e	11.27f	1.93d
	9 month	13.84c	12.0b	70.70g	66.0g	10.18g	1.66g
	12 month	14.56a	18.0a	67.40h	52.0h	8.870h	1.57h
LSD at 5%		0.0146	1.4614	0.0107	0.9361	0.0162	0.0090

Means followed by the same letter in each column are not different significantly according to least significant difference (LSD) at 5% probability level.

Interactive effect of storage length and storage method

Interaction of storage method and storage length had significant effect on seed moisture, test weight, fungal incidence, germination ability, protein content and ash/mineral content (Table 2). Significantly highest germination ability (94.0%), test weight (73.66 kg/hL), protein content (12.45%) and ash/mineral content (1.98%) were found in seeds stored in straw-clay bin at 3 month while significantly least values (52.0%, 67.40 kg/hL, 8.87% and 1.57%, respectively) of these parameters were noted in bulk covered store for 12 months. The fungal incidence was greater (18.0%) in seed samples taken from bulk covered store for 12 months storage and the lowest fungal incidence (2.0%) was recorded in straw-clay bin for 3 months duration. The highest seed moisture content (14.56%) was observed in seeds stored in bulk covered store at 12 months storage time.

Discussion

The quality of food is maintained by controlling the seed's moisture content, surrounding temperature and humidity levels. The spoilage microbes and fungi grow and develop when the optimum moisture and temperature achieved. At experimental site the relative humidity and ambient temperature were ranged between 62 and 76% and 23.3 and 40 °C, respectively throughout the storage time. This humidity and temperature conditions were optimum for the growth of insect-pest for causing highest damage and highest contamination. The optimum temperature for the growth of insects inside the stored seeds ranged between 25 and 33 °C (Ilelejia *et al.,* 2007; Fields, 1992). Nasir *et al.* (2003) have found the mould growth and insect infestation was more in wheat seeds having greater moisture during storage whereas the seeds with least moisture level (9%) indicated no infestation during storage in polypropylene bags for 60 days. The previous work of Abramson *et al.* (1990) indicated that in order to prevent fungal growth the storage temperature should be below 20 °C and the moisture content should be below 15%.

The results of the present study indicated that seed moisture content was significantly affected by storage method, storage length and their interaction. The higher seed moisture content was recorded in samples from bulk covered store than from straw-clay bin during whole storage time (12 month). The presence of high seed moisture in this store might be due to greater respiration of seed, insects and fungi. Water vapors result due to excessive respiration of stored seeds gives rise to the humidity inside the storage structure (Sanchez-Marinez *et al.*, 1997). Previous studies have also found that during storage seed moisture increase with the increase in metabolic products of fungi and insects (Girish *et al.*, 1975; Sinha, 1984; Mills, 1983). The maximum seed moisture content could also be due to fluctuation in relative humidity and ambient temperature with storage length. Every food commodity has its own particular balance between the moisture it contains and water vapor in the air. Stored seeds are hygroscopic and pickup moisture under humid conditions, exchange of moisture occurs between stored seed and the storage environment until an equilibrium is reached (Abba and Lovato, 1999; Ogendo *et al.*, 2004). Number of studies have observed an increase in seed moisture under high humidity conditions of the surrounding during storage in various structures such as jute bags, metal bins and polythene bags (Hruskova and Machova, 2002; Malaker *et al.*, 2008; Hossain *et al.*, 2011).

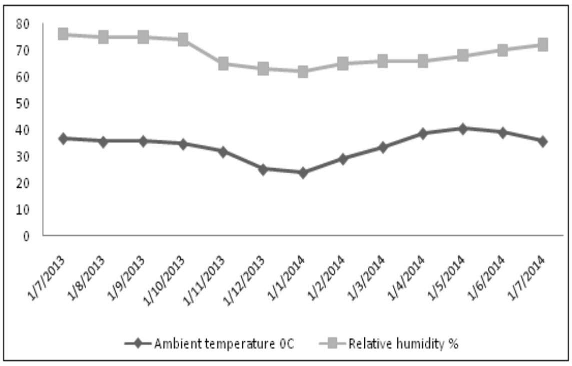

Fig. 1. Relative humidity (RH, %) and ambient temperature (T, °C) of the study area during experiment.

Seed germination test is considered as the most important quality test in evaluating the ability of seeds to germinate normal seedlings. Seed germination ability reduced gradually with the progress of storage length and the lowest value was observed in seeds stored in bulk covered store as compare to straw-clay bin. The maximum loss of germination ability in bulk covered store may be due to greater temperature and moisture conditions. It was observed that high seed moisture and temperature conditions during storage in various types of structures affect negatively on seed germination ability (Sathya *et al.*, 2008; Nithya *et al.*, 2011; Singh *et al.*, 2000). The loss of germination ability may also be due to damage of seed embryos by fungal and insect attack. The presence of insect and fungi in different seed storage structures decrease seed germination percentage as observed by various researchers (Demianyk and Sinha, 1988; Fleurat-Lessard, 2002; Lemessa *et al.*, 2000).

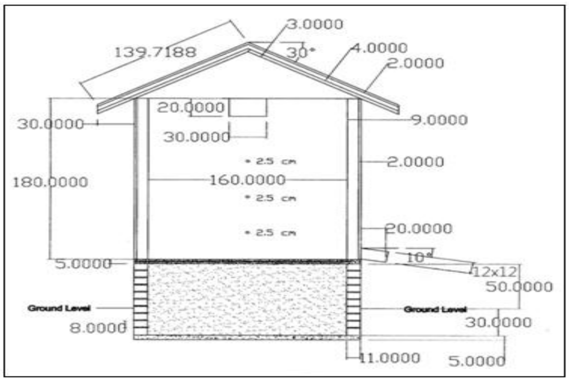

Fig. 2. Schematic diagram of the straw-clay bin.

Fungi are major cause of spoilage of stored seed and the role of fungi in the loss of seed cannot be ignored. The fungus that grows most frequently in stored wheat includes mainly of *Penicillium* and *Aspergillus* species, which rapidly grow on moist seed. Fungal incidence was found in freshly harvested wheat seed which further increased with the passage of time and the highest rate of increase was recorded in seeds stored in bulk covered store than in the straw-clay bin. The maximum values of fungal attack in the bulk covered store can be attributed to higher moisture and temperature conditions. High seed moisture and temperature resulting from moisture migration, leaks in stores and storage of high moisture seed significantly increased fungal incidence during storage in different structures (Naoufal *et al.*, 2012; Paraginski *et al.*, 2014; Aktaruzzaman *et al.*, 2010). The deterioration of seed by fungi might also be due to the presence of insects. Insects could act as vectors by transporting fungal spores on their bodies, and contaminating seed as they moved about. Feeding by insects breaks the pericarp, rendering seed more vulnerable to invasion by storage fungi (Tuite *et al*., 1985; Barry *et al*., 1992). It has been demonstrated that metabolic activity of insects can result in increased relative humidity, and thus providing favourable conditions for the growth of fungi (Sauer and Burroughs, 1980).

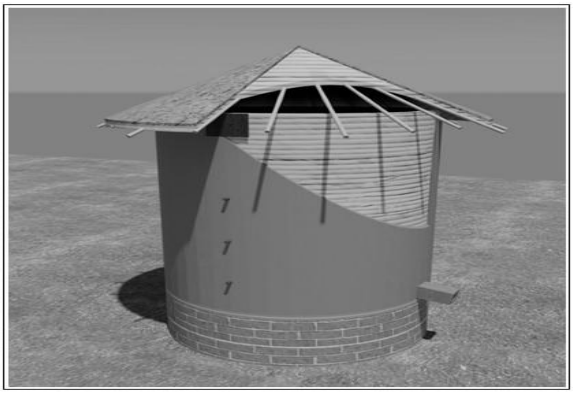

Fig. 3. Three dimensional view of the straw-clay bin.

Fig. 4. Wheat seed stored in bulk covered store.

Test weight is one of the most widely used criteria for assessment of grain quality in which weight of a fixed volume of seed is obtained. The higher test weight of wheat seeds yield more flour when subjected to milling (Hook, 1984). A reduction in seed test weight was noted throughout the experiment and the reduction was higher in seeds stored in bulk covered store than in straw-clay bin. The lower test weight in bulk covered store may be due to higher seed moisture content. It is assumed that high moisture content causes wheat seeds to undergo self-digestion which results in nutrients loss to yield energy for respiration, thereby affecting the test weight of seeds. Previous studies noted that increase in seed moisture, seed temperature and storage time lead to a significant decrease in seed test weight (Chaudhry *et al*., 1987; Gonzalez-Torralba *et al*., 2013; Santos *et al*., 2010). The presence of microbes and insects may also be the reason of loss of seed test weight during storage. The reason behind that are the insects and fungi grow upon feeding the carbohydrate content present inside the endosperm of seed which reduce the test weight and increase the seed damage.

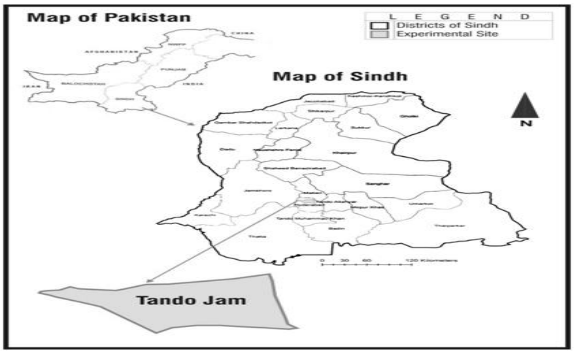

Fig. 5. Map of Pakistan and experimental site.

Protein content in wheat grains helps to determine the flour quality and its suitability for preparation of different products. Seed protein reduced with the passage of storage period. The greater rat of decrease of protein was noted in seeds stored in bulk covered store in contrast to straw-clay bin. This maximum decrease of seed protein in bulk covered store may be due to increased moisture and temperature of the environment. High temperature and moisture of storage structure also leads to the activation of proteolytic enzymes of stored seeds. This might have decreased the protein content of the wheat during storage. A number of studies indicated a significantly decrease in seed protein content with higher temperature and moisture conditions during storage in different structures (Nasir *et al*., 2003; Onigbinde and Akinycle, 1988; Sur *et al*., 1993). The decrease of seed protein during storage might also be due to the increased fungal and insect attack. The aflatoxins produced by fungi consume proteins to grow and multiply thereby reduce the protein value of stored wheat grains. A reduction in seed protein content during storage in various structures for different storage time because of the use of proteins as a source of energy for development of fungi and insects was recorded by many researchers (Bhattacharya and Raha, 2002; Robinson *et al.*, 1974; Arian *et al.*, 2004).

The ash content of any product represents its mineral content. As higher the ash content of the product, greater will be the mineral concentration. A decrease in seed ash content was recorded throughout the study and the maximum decrease of seed ash content was observed in bulk covered store than in straw-clay bin. This may be due to respiration of stored wheat grains which causes the oxidation of carbohydrates in the presence of oxygen for the production of energy. This may also leads to the subsequent decrease in ash content and food energy values due to loss of carbon during respiration (McKenzie *et al.*, 1980). The loss of seed ash content may also be due to insect and microbial attack. Various studies have found a significantly decrease in seed ash content due to growth of fungi during storage in different types of stores (Saleemullah *et al.*, 2006; Bamaiyi *et al.*, 2006).

Conclusion

The deterioration rate in seed samples taken from straw-clay bins was about half of the overall deterioration recorded in the samples collected from the traditional bulk covered store. The straw-clay bins retained good quality seed (high seed germination percentage, low fungal incidence, and high test weight, protein content and ash/mineral of seed) for longer periods of time which will help to raise the country's economy, poverty alleviation and reduce hunger.

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