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Full Length Article

Maintaining Seed Quality of Maize and Wheat through Dry Chain Technology in Pakistan

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Abstract

Seed is inevitably deteriorated during storage and higher seed moisture content is the primary cause of this decline in seed quality. Dry Chain is a valuable tool, by using moisture proof hermetic containers to preserve seed quality throughout supply chain. This study evaluated and compared the performance of wheat and maize seed in different hermetic storage packaging (Super bag, Anaaji bag and drum) with conventionally used woven polypropylene bags after six months storage in ambient conditions. Seed moisture content was increased up to 11.53 and 13.55% in wheat and maize respectively when packed in polypropylene bags while it remained low (approximately 10 and 11.4% in wheat and maize respectively) when packed in hermetically sealed bags and drum. Germination was maintained in both cereal seeds stored in hermetically sealed Super bag, anaaji bag and drum while it reduced in polypropylene bags as compared to initial seed quality. Seed stored in polypropylene bag deteriorated quickly, which resulted in loss of seed vigour as indicated by higher malondialdehyde contents and electrical conductivity of seed leachates. It can be concluded that maintenance of seed dryness with hermetic storage is useful in preservation of seed quality and related attributes under high relative humidity environment.

Keywords: Cereal seed; Seed vigour; Hermetic storage; Seed deterioration; Seed moisture contents

Introduction

In 2050 food security will be a main concern, as world's population will be approaching 10 billion (Bellemare *et al*., 2017). In cereals, wheat and maize are utilized as major dietary components because of nutrition requirements (Hanger *et al*., 2012). In FAO survey, one third of produce equal to 1.3 billion tons worldwide is wasted due to poor postharvest handling (Gustavsson *et al*., 2011). In past thirty years, major research efforts have been made towards increasing yield of agricultural commodities *e.g*., 95% but only 5% endeavours were allocated to emphasize loss in post-harvest management (W.F.L.O., 2010).

Farmers store their produce to save from undulating weather behaviour in locally woven jute and polypropylene bags, which are highly prone to deterioration due to fluctuating weather (Afzal *et al.*, 2017). As result of seed quality loss, farmers are in oppression to trade their produce at nugatory prices soon after the harvest (Tefera *et al.*, 2011). Storage losses of seeds are of two types, direct losses in physical quality because of physical damage and indirect losses due to reduction in nutrition or quality of stored product (Boxall, 2002). Biotic factors (fungi and insects) and abiotic factors (relative humidity, moisture and temperature) are involved in loss of seed quality during storage (Abedin *et al*., 2012). Insects account 30–40% of total losses in cereals during post-harvest environment (Abass *et al.*, 2014) and about 25% losses are in head of abiotic factors (Shelar *et al.*, 2008). Among abiotic factors, important one that link seed moisture and deterioration with seed quality is ambient humidity with the influence of environmental temperature (Hill and Cunningham, 2007; Bradford *et al*., 2018).

Wheat crop harvested in dry environment had average moisture content of 9.3% which later increased because of increase in environmental humidity (Al-Mahasneh and Rababah, 2007; Afzal, 2018). In spring maize moisture content at the time of harvest is not at limit <15% for safe storage, further drying is required to reduce seed moisture content at safe limit (Kaaya *et al*., 2005). Safe moisture content for cereals ranges from 12–14% (Ghassemi-Golezani *et al.*, 2010). In Pakistan, both dry and wet seasons are practiced. In monsoon, conditions are humid and seeds stored in conventional bags that equilibrate with environment cause subsequent increase in moisture (Afzal, 2018). With the increase in seed moisture contents in high RH cause post-harvest quality loss in traditional jute and cloth bags (Wagacha and Muthomi, 2008). All these factors contribute to common consequences which reduce germination because of loss in seed vigour (Rajendran, 2003).

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An innovative climate smart storage "Dry Chain technology" is effective to maintain seed dryness throughout supply chain after harvest. Dry chain is drying of produce at safe moisture and sealed in hermetic packaging to maintain its viability (Bradford *et al.,* 2018). Use of Dry Chain is beneficial to protect the seed quality of cereals (Bakhtavar *et al.*, 2019a). At safe moisture level, hermetic sealed storage ensures reduction in 98% storage losses with addition of seed quality preservation and viability maintenance (Kumar and Kalita, 2017). Hermetic packaging materials maintain seed vigour, viability and moisture content in adverse environmental humidity and temperature during storage (Afzal *et al*., 2017). Hermetic storage can help farmer's economic status and strengthen food security with reduction in food losses.

Pakistan has both dry and wet climatic zones where two cropping seasons are practiced, *i.e.*, Rabi (October/November to April/May) and Kharif (June/July to November/December). Seeds harvested in either season go through summer monsoon rains where they lose quality mainly due to the combination of high moisture contents and high temperature (Afzal, 2018). Lack of quality seed and storage facilities in both public and private sectors has been identified as a constraint for the development of the seed sector in Pakistan. The present study provides methodology to preserve wheat and maize seeds by implementing dry chain technology, which prevents post-harvest losses before the start of next growing season.

Materials and Methods

Experimental Details

Seeds were stored in Seed Science and Technology building, University of Agriculture, Faisalabad, Pakistan (31.4180º N, 73.0790º E) at ambient environment in store house (Fig. 2). This study was conducted for six months (from February 26 to August 30, 2018). Data logger (Rhino Research, Thailand) was installed in storehouse to monitor environmental RH and temperature during storage. Wheat (95% initial germination and 10.49% seed moisture) and maize (98% initial germination and 12.13% seed moisture) seeds were purchased from local seed market. Completely randomised design (CRD) was used with three replications.

Conventional vs Hermetic Storage Systems

Seed was packed in different packaging materials for six months (Fig. 1). Hermetically sealed materials 1) locally manufactured plastic airtight drum of 160 kg capacity was covered with plastic lid having digital hygrometer, which continuously measures moisture content of seed in the drum, 2) locally made Anaaji bag which is an improved multilayer hermetic grain storage technology having 50 kg capacity and requires no fumigation or chemical application that preserves quality and germination capacity of stored seeds and 3) imported Super Bag having 50 kg capacity provided by GrainPro Inc., U.S.A. For conventional storage, polypropylene bag of 40 kg capacity was used. Seed samples were taken at the time of initiation (February 26, 2018) and at the end of experiment (August 30, 2018) in 1 kg plastic zip lock bag from each experimental unit to analyse different physiological and biochemical parameters.

Seed Moisture Content

Seed moisture content was calculated according to International Seed Testing Association (I.S.T.A., 2015). Course grinded seed sample (5 g) in three replications were placed in an oven at 103 ± 2ºC for 17 h and moisture content was determined by using formula;

$$\text{Seed moisture content (\%)} = \frac{\text{Fresh Weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

Germination

Germination of seed samples was tested according to International Seed Testing association (I.S.T.A., 2015). About 400 seeds were placed on paper towel (VICTORY paper towel, 25×25 cm) in four replications of 100 seeds and placed in a germinator (SANYO Japan, MIR-254) at 25 ± 2°C and 65% RH. Final germination was evaluated after 6 days by using formula;

$$\text{Germination (\%)} = \frac{\text{Germinated seeds}}{\text{Total seed}} \times 100$$

Accelerated Aging

Prescribed protocol of accelerated aging test for vigour evaluation of seed samples was conducted according to International Seed Testing Association (I.S.T.A., 2015). About 400 seeds counted with seed counter (CONTADOR Pfeuffer) and were placed at 95% RH and 45°C temperature in aging chamber (Xenon SUS304) for 24 h. Later on germination test was conducted to access seed vigour.

Electrical Conductivity of Seed Leachates

About 50 seeds were dipped in 250 mL of distilled water for 24 h at 25 ± 2°C. Electrical conductivity of seed leachates were measured with conductivity meter (HI 99300 of Hanna Instruments, Japan) and conductivity was determined by using formula;

$$\text{Conductivity } (\mu\text{S/cm/g}) = \frac{\text{Conductivity reading } (\mu\text{S/cm}) - \text{Background Reading}}{\text{Weight of the replicate}}$$

MDA Contents

Fine grind seed (1 g) was mixed in 7 mL 10% trichloroacetic acid (TCA) solution and homogenized in mortar pastor for one minute (Zheng and Tian, 2006).

Fig. 1: Storage of cereal seeds in different packaging materials

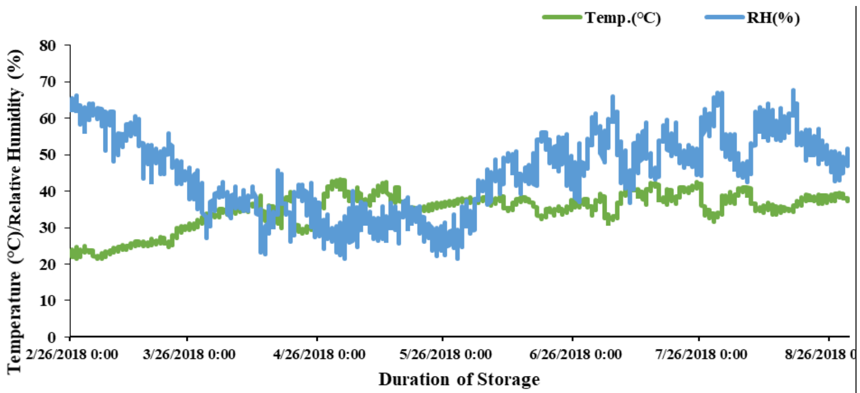

Fig. 2: Ambient environment relative humidity (%) and temperature (°C) of store house (February 26, 2018 to August 30, 2018) during wheat and maize seed storage

Homogenous mixture was subjected for 15 min at approximately 10000 rpm for centrifuge. About 2 mL supernatant was collected and mixed with 2 mL of 0.6% tribarbituric acetic acid (TBA) in 20% TCA. Then mixture was heated in water bath at 95 ± 5°C for 25 min. After heating, mixture was centrifuged again to take supernatant and UV absorbance was observed in spectrophotometer (Spectrophotometer UV 4000) at 600, 532 and 450 nm wavelengths. Observed readings was analysed by using formula;

$$MDA = 6.45(A532 - A600) - 0.56A450$$

Statistical Analysis

Completely Randomized Design (CRD) was used in three replications for data analysis using statistical software Statistix 8.1. Seed quality parameters were evaluated in different packaging material in each experimental unit. Treatment means were compared using LSD Test at $P \leq 0.05$.

Results

Hourly data was recorded through data logger (Fig. 2) to determine temperature and RH during storage period. Relative humidity of storage ranged from 21.4 to 67.8% and temperature from 21.4 to 43.3°C. During storage, there was a gradual increase in temperature from January to August 2018. Maximum temperature 43.3°C was recorded on May 1st, 2018 and minimum was 21.4°C on March 4^{th,} 2018. Overall, significant variability in RH was observed in storage and maximum RH was 67.8% on August 17th, 2018.

Wheat seed germination was maintained in hermetic containers (Super Bag, anaaji bag and anaaji drum) whereas quickly declined in seed stored in polypropylene (PP) bag (Fig. 3). The germination declined from 95% initial germination to 91, 90 and 89% in Super Bag, anaaji bag and anaaji drum respectively. Maize seed stored in super and anaaji bags maintained maximum germination (95%) followed by anaaji drum (92%). In conventional storage, germination was significantly low in maize seed stored in PP bag (76%) as compared to initial germination quality (98%) (Fig. 3).

Wheat and maize seed storage in PP bag at 10.49 and 12.11% initial seed moisture contents respectively had significantly ($P \leq 0.05$) highest moisture contents after six months of storage. Minimum moisture contents of both wheat and maize seeds were recorded for the seed stored in Super Bag, Anaaji bag and drum (Fig. 4).

Significant interaction ($P \leq 0.01$) was observed regarding electrical conductivity of wheat and maize seed stored in different packaging materials (Fig. 5). In PP bag, wheat and maize seeds after six months of storage had high conductivity values (50.67 and 23.33 μS cm^{-1} g^{-1}) as compared to control. In wheat, seed stored in anaaji bag had 32 μS cm^{-1} g^{-1} electrical conductivity of seed leachates. Minimum EC (30 μS cm^{-1} g^{-1}) was recorded in super bag having wheat seed.

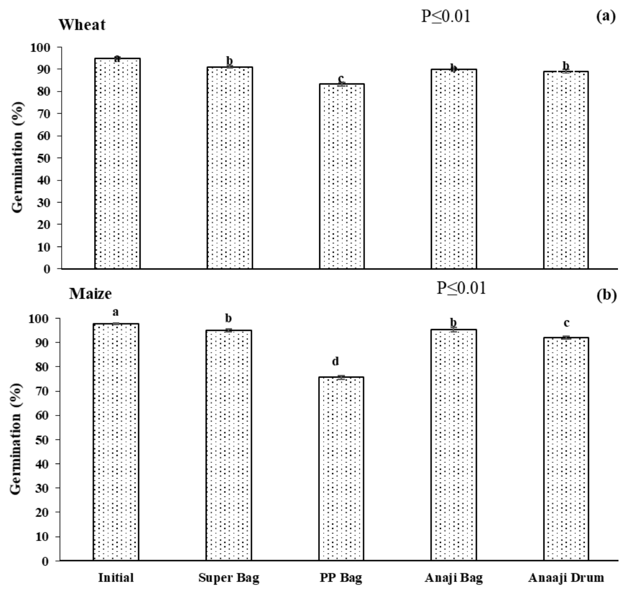

Fig. 3: Wheat and maize seed germination after six months storage in different packaging materials

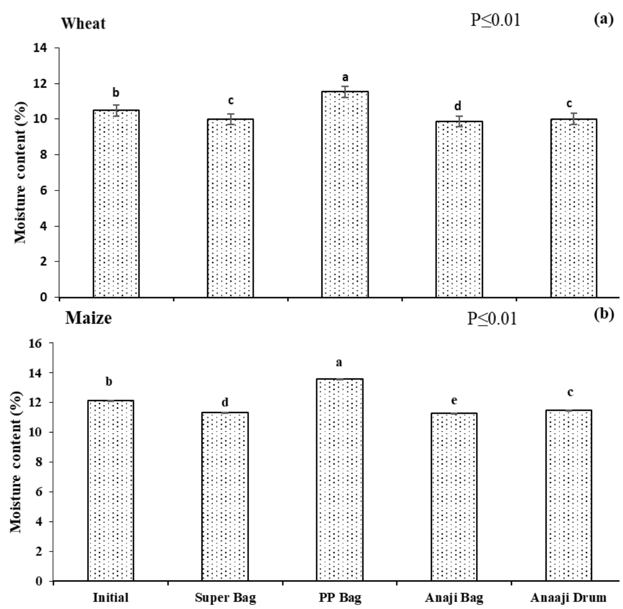

Fig. 4: Wheat and maize seed moisture contents (%) after six months storage in different packaging materials

Seeds of wheat with initial 91% and maize with 95% germination subjected to accelerated aging had significant effects ($P \leq 0.01$) in different packaging material (Fig. 6). Wheat seed stored in Super Bag had maximum germination (86%) after accelerated aging test as compared to PP bag (72%). In maize, maximum germination was recorded in super bag (84%) followed by anaaji bag (83%). Significant loss in vigour (22%) was observed in PP bag.

Seed storage in different packaging material had significant effect ($P \leq 0.01$) on malondialdehyde contents

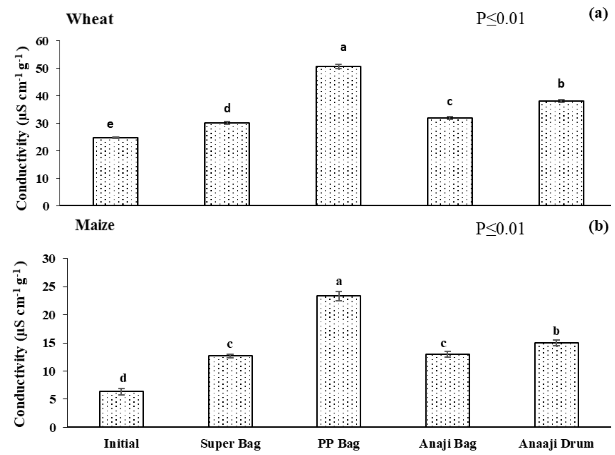

Fig. 5: Electrical conductivity (μS cm^{-1} g^{-1}) of seed leachates of wheat and maize after six months of storage in different packaging materials

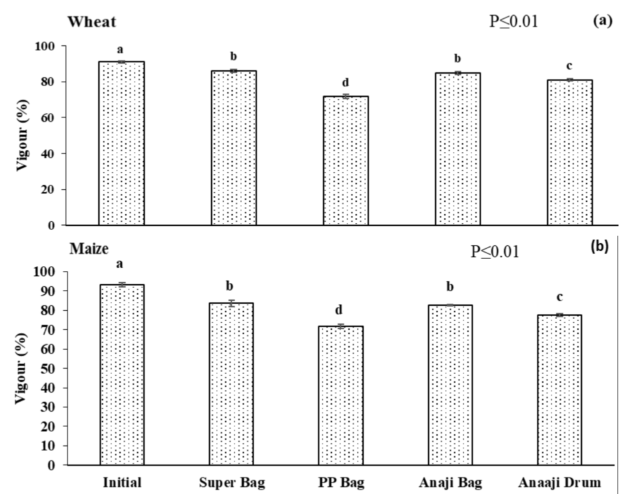

Fig. 6: Seed vigour of wheat and maize after six months of storage in different packaging materials

(MDA) of wheat and maize seeds after six months storage. Wheat and maize seed stored in PP bag gave maximum values (1.40 and 0.45 n mole g^{-1}) of MDA contents (Fig. 7). All other seed stored in different storage material have significant different with low MDA degradation.

Discussion

Moisture from ambient relative humidity is the main culprit, which quickly deteriorates seed quality during storage (Afzal, 2018; Bakhtavar *et al*., 2019a). However, maintenance of seed dryness during storage can preserve the seed quality (Afzal *et al*., 2017; Bakhtavar *et al*., 2019b). Bradford *et al*. (2018) emphasized that dry chain technology could reduce storage losses of seeds by maintaining low moisture contents in hermetic containers throughout the supply chain. The present study evaluated the efficiency of

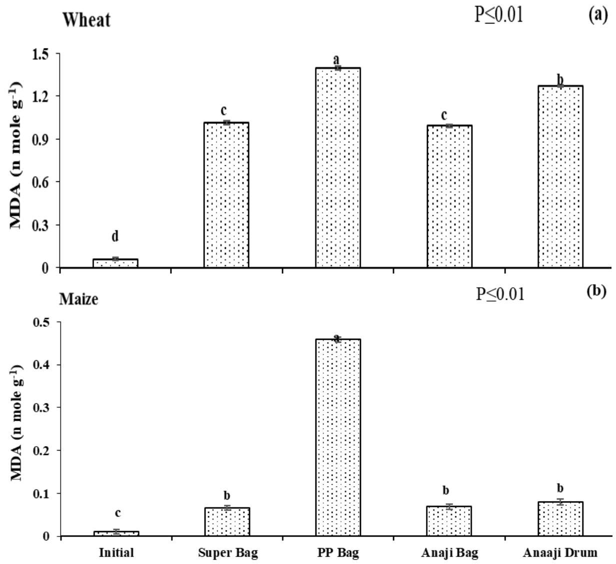

Fig. 7: Wheat and Maize seed MDA contents after six months of storage in different packaging materials

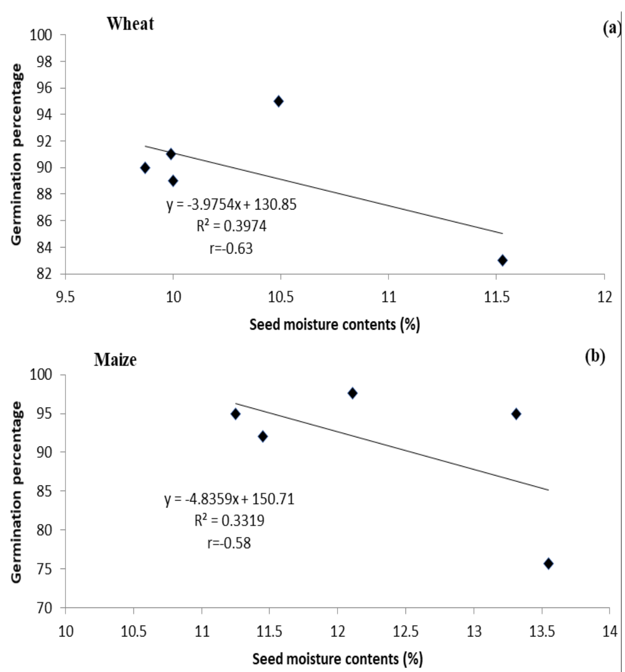

Fig. 8: Correlation between seed moisture contents and germination percentage of wheat and maize seed after six months storage in different packaging materials

various types of hermetic containers for wheat and maize seeds at ambient environment. Germination of both wheat and maize seeds was maintained in all hermetic bags compared to polypropylene bags. Maintenance of seed quality in Super Bag along with anaaji bag and drum indicate low permeability to the incoming water vapours and oxygen which prevents from fungal and insect growth (Williams *et al*., 2017). Hence, hermetic storage is efficient and useful to maintain germination with no change in moisture during storage (Bakhtavar *et al*., 2019b).

Farmers in developing countries including Pakistan store their produce in traditional storage material like jute, polypropylene and cloth bags (Hell *et al.*, 2014). At high humidity especially in the season of monsoon, seed equilibrates with RH that rises up moisture of seeds stored in conventional porous packaging material (Afzal *et al*., 2017; Williams *et al*., 2017). In present study, a significant germination loss of wheat (14%) and maize (22%) seeds in polypropylene bags was due to increase in moisture up to 1.04% in wheat and 1.43% in maize. It is evident from the literature that 1% increase in seed moisture content reduces half of seed shelf life (Harrington and Kozlowski, 1972). Thus, higher seed moisture content is detrimental to seed viability after harvest (Tubbs *et al*., 2016). A negative correlation between seed moisture contents and germination percentage was observed in wheat (r = -0.63) and maize (r = -0.58) seeds when packed in different packaging materials for six months (Fig. 8).

Seed moisture contents raised up in porous polypropylene bags in Monsoon season when relative humidity was at its peak. Under such conditions polypropylene bags having large pore size were unable to protect grains from ambient relative humidity (Martin *et al.*, 2015).

Electrical conductivity of seed leachates gives the estimation of seed vigour and degree of seed deterioration. In wheat and maize, high extent of seed deterioration was observed in polypropylene bag while low electrical conductivity was recorded in seeds stored in various hermetic containers. High deterioration in seeds packed in porous polypropylene bags was due to higher seed moisture contents that ultimately resulted in loss of seed vigour (Murthy *et al*., 2003; Shelar *et al*., 2008). Accelerated aging test also indicated that seed stored in polypropylene bags showed loss of vigour up to 19.34 and 25% in wheat and maize seeds respectively at 95% RH and 45°C (Fig. 6). The results corroborated with the findings of Rajjou *et al*. (2012) that high rate of seed deterioration in aged seeds resulted in loss of seed vigour and viability (Rajjou *et al*., 2012).

Malondialdehyde (MDA) contents are biomarkers in lipid peroxidation, which are directly related to seed deterioration in storage and reduced activities of antioxidants (Kibinza *et al*., 2006). High MDA contents of maize and wheat seeds stored in conventional bags were triggered by higher seed moisture contents when exposed to high temperature and relative humidity (Fig. 2 and 7). High moisture exhausted stored food reserves, which resulted in lipid peroxidation in embryo and accelerated solute leakage (Liu and Xu, 2011). Thus, it is clear from present investigation that minimum moisture content and better storage material is essential for the maintenance of seed quality during storage. High vigour of seeds packed in hermetic bags and drum relates to low level of MDA contents, which protect seeds from oxidative damage and seed deterioration (Bakhtavar *et al.*, 2019b).

Conclusion

Seed viability and vigour was maintained in hermetically sealed seeds due to low seed moisture contents because of strong barrier in packaging material against water vapours and oxygen. However, polypropylene bags are not recommended for seed storage in the season of high relative humidity. Thus, maintaining the Dry Chain through hermetic system for cereal seeds at low moisture contents would help to preserve seed quality throughout the supply chain. Moreover, anaaji bags and drums are locally made hermetically sealed containers which are very economical and productive as compared to imported Super Bags.

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