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# Storability of Different Hermetic Bags on Seed Quality Attributes of Maize in Khumaltar, Lalitpur

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## ABSTRACT

To evaluate the comparative superiority of exotic hermetic seed storage bags versus locally available bags supplemented with or without desiccants for on-farm seed storage of smallholders, an experiment was conducted in the National Seed Science and Technology Research Centre (NSSTRC) of Nepal Agricultural Research Council (NARC) from May 2017 to June 2019. Maize seed variety Manakamana-3 was allocated in 8 treatments based on storage devices with three replications in a completely randomized design (CRD). The 98% initial germinating seed was stored in eight different storage containers *viz.*, S1, Super grain bag; S2, PICS bag; S3, Safe Grain bag; S4, 400-gauge plastic bag; S5, 400-gauge plastic double liner; S6, 400 gauge + metal bin; S7, 400 gauge + Zeolite beads; S8, 400 gauge + roasted wheat. All seed attributing data were taken in tri-monthly intervals for two and half years. In the first year, all seven treatments were found statistically at par results for germination above 85% by meeting the Nepalese maize seed standard except 400-gauze plastic bag-single liner. However, significant differences were seen in each treatment in the second year. Results on germination of storage structures with desiccants *viz*., 400 gauge + Zeolite beads, and 400 gauge + roasted wheat were found superior to any other storage structures such as PICS bag, Super grain bag, Safe grain bag, 400 gauge + metal bin, & 400-gauge plastic double liner. Whereas, the single liner of a 400-gauge plastic bag was found non-suitable and found vulnerable to fungal infestation in long-run storage in ambient storage conditions. Hence, it was concluded that the locally fabricated seed storage bags provided equal results to exotic hermetic bags for one season seed storage in Mid-hill, humid and sub-temperate condition of Nepal and hence, found economical modified atmospheric storage (MAS) option for small holder farmers.

**Keywords**: hermetic bag, seed quality, maize storage, desiccant

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## INTRODUCTION

Maize (*Zea mays* L.) is an important staple food crop produced by the majority of smallholder farmers that provides household food security through direct consumption and income generation. It is a multipurpose crop (Grassini and Cassman, 2012) as well as the most versatile emerging crop having wider agro-climatic adaptability

(Chandrasekaran et al 2010). Seed is the elementary unit of crop production, and its quality is a primary determining factor of yield and nutrition (Louwaars and Boef 2012). It is not only a vehicle for promoting productivity, nutrition, and resilience, but also an entry point for achieving multiple development goals and technology transformation among the farmers (McGuire and Sperling 2016). In Nepal, the formal seed system covers around 15-20% of total seed requirements whereas 80-85% of seed demand is fulfilled by informal seed systems (SQCC 2019). Therefore, the quality aspect of the informal seed system is equally important. Practices of smallholder farmers for production, preservation, and exchange mechanisms should be prioritized to strengthen the informal seed system prevailing among the farmers (Almekinders and Louwaars 1999).

At a commercial level, seeds can be preserved in cold storage. Much research has been dedicated to improving storage technologies through controlled atmospheric storage (CAS). Those researches on storage are practically incompatible with the seed storage of the smallholder farmers. However, CAS technologies are rarely available or affordable to small-scale farmers because of the high investment cost and other technological barriers (Jeremiah and Gibson, 2001). Existing on-farm, mostly traditional storage practices of small-holder farmers are inadequate to protect the seeds from attack by insects, rodents, monkeys as well as molds in dominant maize-growing areas of Nepal (Bhandari et al 2015). Moreover, the locally used storage materials like fertilizer sacks and earthen pots retained the seed quality only for 6 months in maize in the ambient environment of Mid-hills (Bhandari, et al. 2017). It has been long recognized that there is an urgent need for a safe, pesticide-free, and economically viable farm-level seed storage technology to be developed.

In this regard, the present investigation was carried out to illuminate this unexplored area of the comparative superiority of exotic hermetic seed storage bags versus locally available hermetic bags with or without adding desiccants in on-farm seed storage conditions especially focused on smallholder farmers.

## MATERIALS AND METHOD

The experiment was conducted in the laboratory of the National Seed Science and Technology Centre (NSSTC), Khumaltar, Lalitpur (Longitude 85°10’ E and Latitude 27°39’N; Altitude, 1335 m asl), Nepal from May 2017 to June 2019. Foundation seed of the Manakamana-3 variety produced in the current season by the National Maize Research Program (NMRP) was procured for the research purpose. Ten moisture tests were conducted from the lot of seed which revealed an average MC of 12.5% by using Wiley Moisture Meter 55. The seed lot was further sun-dried for two days in a collapsible seed dryer. After sun drying, the final moisture content of the seeds was recorded as 11.7%. Similarly, the average 98% initial germination was recorded from the whole lot. The following eight treatments each of which accommodates 60 kg seeds replicated thrice and laid out in a Completely Randomized Design (CRD). The amount of cooled reactivated zeolite beads as a desiccant was calculated by using a special protocol for using zeolite desiccant beads to dry seeds. Calculations on 20-degree ambient temperature, 20% bead capacity, and projected 30% in vitro relative humidity, 166-gram zeolite beads per kg seed (10 kg per 60 kg seeds) storage was used. Similarly, In order to prepare the treatment with wheat as a desiccant, 30 kg of wheat was oven-dried for 72 hours at 65 degrees Celsius. For one replication, 10 kilograms of roasted wheat divided into four net bags of 2.5 kg roasted wheat were made stratum after six inches of the seed layer.

A digital hygrometer was placed inside each container to record the temperature and RH and all sets were stored in ambient condition. The initial seed quality attributes like germination, and seed moisture content in each treatment were analyzed at every three months interval. Germination was conducted in germination paper by using between-paper (BP) methods. The oven method was used for assessing the moisture content of the seed as described by ISTA (International Seed Testing Association) rule

**Table 1**. **Details of different treatments used in maize seed storage for thirty months at NSSTRC, Khumaltar since 2017-19**

| Symbol | Treatments | Treatment Description |
|---|---|---|
| T1 | Super grain bag | An exotic hermetic bag having an outer ordinary woven Polypropylene bag with an inner single-liner hermetic bag made of multi-layered recyclable plastic polyethylene from GrainPro company. |
| T2 | Purdue Improved Crop Storage (PICS) bag | An exotic hermetic bag having an outer ordinary woven Polypropylene bag and two inner liners of high-density polyethylene developed by Purdue University. |
| T3 | Safe grain bag | An exotic hermetic bag having an outer ordinary woven Polypropylene bag with an inner single-liner hermetic bag made up of multi-layered (5 layers) gas, moisture barrier EVOH Technology supplied by Green Life Agrotech Company, Pvt. Ltd. |
| T4 | 400-gauge plastic bag single stratum (SS) | A locally fabricated hermetic bag having an outer ordinary woven Polypropylene bag with a single plastic liner with 100 microns (0.1mm) thickness. |
| T5 | 400-gauge plastic double stratum (DS) | A locally fabricated hermetic bag an outer ordinary woven Polypropylene bag with two Plastic liners each of 100 microns (0.1mm) thickness. |
| T6 | 400 gauge plastic bag + Metal bin | An outer metal bin made up of a 0.45 mm thick zinc-plated metal sheet with a single plastic liner of 100 microns (0.1mm) thickness. |
| T7 | 400 gauge plastic bag + Zeolite beads | An outer ordinary woven Polypropylene bag with a single plastic liner of 100 microns (0.1mm) thickness holding 10 kg Zeolite (Exotic desiccant) in a 60 kg seed in one replication. |
| T8 | 400 gauge plastic bag + Roasted wheat | An outer ordinary woven Polypropylene bag with a single plastic liner of 100 microns (0.1mm) thickness holding roasted wheat (local desiccant) as a desiccant and maize seed at a 1:6 ratio. |

## RESULTS AND DISCUSSION

### Carbon-dioxide concentration

The carbon dioxide concentration measured by the Gas Analyzer revealed significant differences among the various hermetic bags. The highest $CO_2$ retention was reported in Safe grain bags and Super Grain Bags followed by the PICS bag, 400-gauge plastic bag +roasted wheat, and 400-gauge plastic bag double stratum whereas the least retention was observed in the 400-gauge plastic bag single stratum and 400-gauge plastic bag single liner + Zeolite beads (Figure 1).

In hermetic storage, the atmosphere has been modified by sealing the container hermetically, so that a gas composition of low oxygen and high carbon dioxide atmosphere is obtained. The alteration of the atmosphere is achieved either biologically, through the respiration of seeds and other organisms like pathogens and insects present in the seed lot (Bailey, 1965). The local 400-gauge plastic liner materials have significantly higher gas and moisture permeability compared to exotic hermetic bags. The highest $CO_2$ retention in Safe grain bags and super grain bags is due to their inner multilayer liner having gas and moisture barrier materials like Ethylene vinyl alcohol copolymer (EVOH), Ethylene Vinyl Alcohol (EVAL) which has excellent barrier properties for moisture, gases, and volatile products. This improves the seed quality by decreasing colony forming unit (CFU) of molds and insect counts inside the modified atmospheric condition (Cardoso et al 2016).

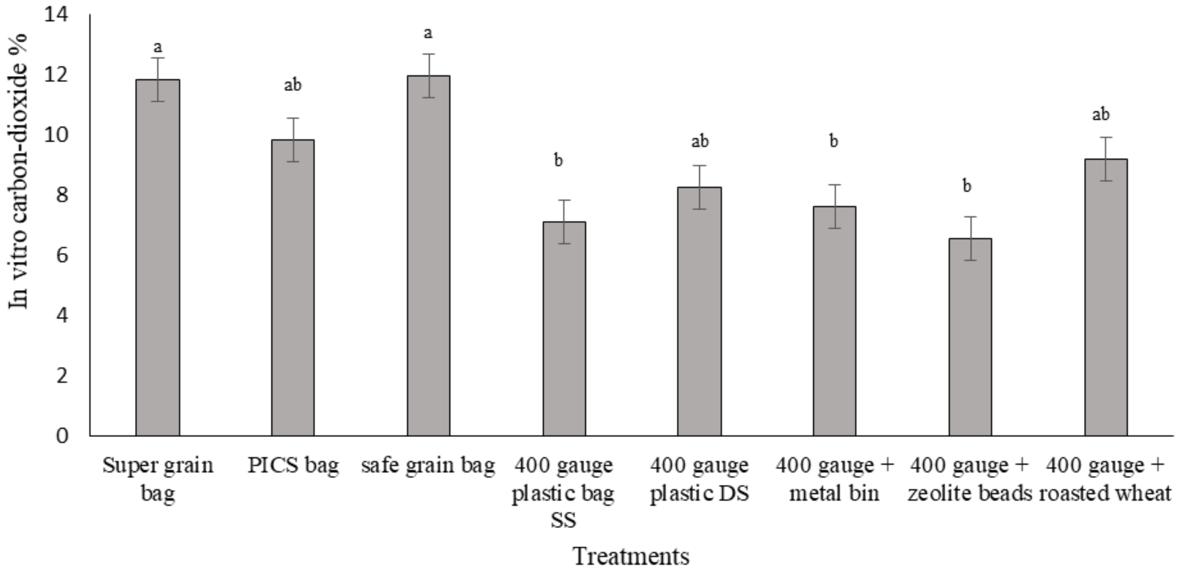


**Figure 1**. **Effect of storage structures on carbon-dioxide retention for three months of maize seed storage at NSSTRC, Khumaltar since 2017-19**

**Germination Test**

Germination percentage was similar in all kinds of storage structures till six months. Under nine months of storage, a difference was observed in the germination percentage however, the seeds of all storage structures were within legal seed standards (Table 2).

**Table 2. Effect of storage structures on germination percentage in maize for fifteen months storage at NSSTRC, Khumaltar since 2017-19**

| Treatments | Germination percentage at storage duration | | | | |
|---|---|---|---|---|---|
| | 3-month | 6-month | 9-month | 12-month | 15-month |
| Super grain bag | 95.9 | 91.5 | 88.8[a] | 86.8[a] | 81.2[b] |
| PICS bag | 96.2 | 92.1 | 88.1[a] | 87.4[a] | 82.5[ab] |
| safe grain bag | 95.6 | 91.8 | 89.4[a] | 87.0[a] | 82.0[b] |
| 400-gauge plastic bag (single stratum) | 93.8 | 88.3 | 86.2[b] | 81.9[c] | 79.1[c] |
| 400-gauge plastic (double stratum) | 94.8 | 89.8 | 88.3[a] | 85.5[b] | 80.9[bc] |
| 400 gauge + metal bin | 95.3 | 91.0 | 89.1[a] | 87.5[a] | 81.8[a] |
| 400 gauge + Zeolite beads | 97.9 | 93.5 | 89.8[a] | 88.3[a] | 85.2[a] |
| 400 gauge + roasted wheat | 96.1 | 91.5 | 87.9[a] | 86.4[a] | 82.6[a] |
| F value | 0.09 | 0.077 | 0.065 | 0.03 | 0.025 |
| SEm (±) | 1.65 | 1.39 | 1.67 | 1.68 | 1.85 |
| LSD (=0.05) | ns | Ns | 2.34 | 2.59 | 3.16 |
| CV, % | 2.2 | 2.3 | 2.4 | 2.5 | 2.8 |
| **Grand mean** | **92.18** | **91.12** | **85.56** | **83.2** | **81.6** |

Note: ns= non-significance; treatment means followed by a common letter (s) within each column are not significantly different from each other based on DMRT at a 5 % level of significance

Furthermore, the germination percentage remained under the seed standard for up to one year in all structures except 400-gauge plastic bag (single stratum). On ambient storage conditions, the use of desiccants in the storage structure performed better germination in fifteen months of storage. Higher viability was observed in exotic hermetic bags like Super grain bags, PICS bags, and Safe storage bags as compared to locally fabricated hermetic bags where locally fabricated storage structure 400 gauge + roasted wheat showed at par results in the second year of storage.

The inner multilayer liner of exotic hermetic bags viz; Safe Grain Bags, Super Grain Bags, and PICS Bags have gas and moisture barrier compounds which have excellent barrier properties for moisture, gases, and volatile products and hence have low oxygen transmission rate (OTR) and water vapor transmission rate (WVTR) compared to the locally found 400-gauge plastic bags. This is because the viability of maize seed was significantly superior to the 400-gauge plastic bags single liner for yearlong storage.

**Table 3. Effect of storage structures on germination in maize for thirty-month storage at NSSTRC, Khumaltar since 2017-19**

| **Treatments** | **Germination percentage at storage duration** | | | | |
|---|---|---|---|---|---|
| | **18-month** | **21-month** | **24-month** | **27-month** | **30-month** |
| Super grain bag | $75.7^{ab}$ | $74.2^{b}$ | $73.8^{ab}$ | $70.9^{ab}$ | $54.7^{c}$ |
| PICS bag | $76.4^{ab}$ | $75.6^{ab}$ | $75.3^{ab}$ | $72.1^{ab}$ | $58.1^{c}$ |
| safe grain bag | $77.8^{ab}$ | $75.4^{ab}$ | $73.0^{ab}$ | $71.7^{ab}$ | $61.0^{cd}$ |
| 400-gauge plastic bag (single stratum) | $71.2^{b}$ | $54.0^{c}$ | $53.9^{c}$ | $31.2^{c}$ | $7.2^{d}$ |
| 400-gauge plastic (double stratum) | $75.8^{ab}$ | $74.2^{b}$ | $71.6^{b}$ | $68.8^{b}$ | $61.0^{cd}$ |
| 400-gauge + metal bin | $76.3^{ab}$ | $75.0^{ab}$ | $74.9^{ab}$ | $73.6^{ab}$ | $64.0^{cd}$ |
| 400-gauge + Zeolite beads | $81.2^{a}$ | $79.8^{a}$ | $79.0^{a}$ | $78.4^{a}$ | $77.9^{a}$ |
| 400-gauge + roasted wheat | $76.6^{ab}$ | $74.0^{ab}$ | $73.6^{ab}$ | $72.8^{ab}$ | $71.0^{ab}$ |
| F value | 0.033 | 0.023 | <0.001 | <0.001 | <0.001 |
| SEm (±) | 5.67 | 5.90 | 3.98 | 4.23 | 5.29 |
| LSD (=0.05) | 4.41 | 5.64 | 6.67 | 10.2 | 11.21 |
| CV, % | 7.6 | 10 | 10.5 | 11.2 | 11.4 |
| **Grand mean** | **76.37** | **72.8** | **71.9** | **67.4** | **56.9** |

Note: ns= non-significance; treatment means followed by a common letter (s) within each column are not significantly different from each other based on DMRT at a 5 % level of significance

**Moisture content**

The initial moisture contents fluctuated among the seed storage hermetic containers. The lowest moisture contents were observed in the storage structures equipped with the desiccants 400 gauge + Zeolite beads and 400 gauge + roasted wheat followed by exotic hermetic containers. The highest moisture leakage was observed in a 400-gauge plastic bag single stratum which is due to a high water vapor transmission rate (WVTR) compared to the other exotic hermetic bags.

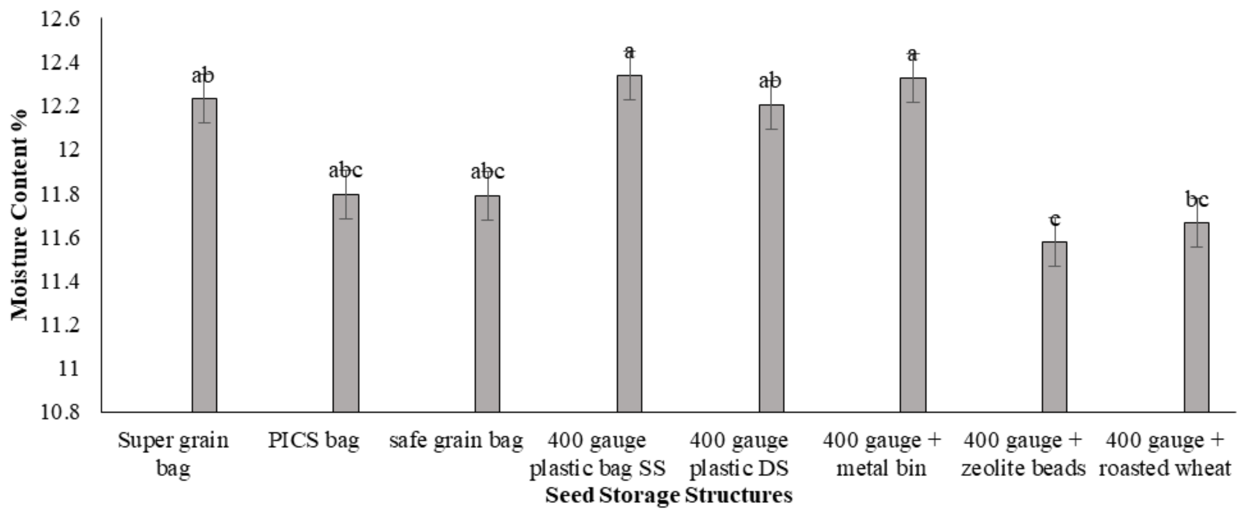


**Figure 2. Effect of storage structures on moisture contents in maize for fifteen months storage at NSSTRC, Khumaltar since 2017-19**

**Economics of Seed Storage**

The seed storage cost for different storage structures ranges from Eighty paisas to 600.50 rupees with a median value of Rs 5.33. Although the 400-gauge plastic bag (single stratum) and 400-gauge plastic (double stratum) were found cheaper than exotic hermetic bags for one season or yearlong storage, 400-gauge plastic (double stratum) or 400-gauge + roasted wheat would be a cheap, sustainable and reliable option for small-holders who do not have access to the exotic hermetic bags. Among the exotic hermetic bags, PICS bags were found slightly cheaper than the other two options however storability is found statistically at par among these three options. For two-year storage, the use of roasted wheat as desiccants is found extremely economical and easily attainable option to that of Zeolite beads in the smallholder farming communities.

**Table 4**. **Cost of different storage structures on maize for thirty-month storage at NSSTRC, Khumaltar since 2017-19**

| SN | Treatments | Seed storage capacity (kg) Capacity | Market price per unit (NRs) | Per kg seed storage cost (NRs) |
|---|---|---|---|---|
| 1 | Super grain bag | 60 | 320 | 5.33 |
| 2 | PICS bag | 60 | 300 | 5.00 |
| 3 | safe grain bag | 60 | 320 | 5.33 |
| 4 | 400-gauge plastic bag (single stratum) | 50 | 40 | 0.80 |
| 5 | 400-gauge plastic (double stratum) | 50 | 60 | 1.20 |
| 6 | 400-gauge + metal bin | 50 | 1020 | 20.40 |
| 7 | 400-gauge + Zeolite beads | 40 | 24020 | 600.50 |
| 8 | 400-gauge + roasted wheat | 40 | 300 | 7.50 |

## CONCLUSION

Based on this study, we can conclude that the locally fabricated seed storage structure 400-gauge plastic bag double stratum is equally efficient and cost-effective as compared to other exotic hermetic bags like PICS, Super-grain, and Safe-storage bags for one-season seed storage in mid-hill of Nepal. Similarly, roasted wheat as a desiccant to maize seed in the ratio of 1:6 was found equally useful and economical than Zeolite for the smallholder farmers to prolong the shelf-life of seed.

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## AUTHORS' CONTRIBUTION

G Bhandari formulated and experimented. S Kaduwal**,** P Pokhrel collected data, BN Adhikari, JB **A**dhikari, and B Bhanda**r**i guided the article for the journal and contributed to and manuscript preparation process too.

## CONFLICTS OF INTERESTS

The authors have no conflict of interest to disclose

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