Journal of Agriculture and Natural Resources (2021) 4(1): 96-110
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v4i1.33231

Research Article

Assessment of the effectiveness of storage structures for maintaining the quality of maize seed stored at different moisture levels

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Received: September 05, 2020; Accepted: November12, 2020; Published: January 01, 2021.

ABSTRACT

One of the main causes of food insecurity is the timely unavailability of quality seeds for smallholder farmers in developing countries. Improved storage technologies are effective in reducing storage losses. Thus, the objective of this research is to assess the traditional and emerging seed storage structures/materials for the maintenance of seed qualities. The effect of different storage conditions (moisture content of seed at the time of storage, i.e. 12±0.15% and 13.5±0.18%; storage containers such as metal bin, earthen pot, Purdue Improved Crop Storage (PICS) bag, and jute bag) on seed qualities of maize were assessed. The seed was collected from Chitwan, Nepal and a laboratory experiment was conducted at the central seed testing laboratory, seed quality control center (SQQC), Hariharbhawan, Lalitpur. The experiment was done using a two-factor complete randomized design in a four replicates design. Data regarding the seed qualities (seed moisture percentage, germination percentage, root and shoot length, and vigor index) just before store and also at 45, 90, 135, 180, and 240 days after storage (DAS) was performed as per the standard followed by International Seed Testing Association (ISTA). The germination percentage, root, and shoot length decreased with increasing storage duration. The seed stored in the higher moisture level had significantly higher seed moisture throughout the storage duration. Seed stored in the traditional structures (jute bag and earthen pot) had lower seed moisture at 120 and 180 DAS. The seed stored at lower moisture resulted in a higher germination percentage, long root, and shoot length. Up to six months of storage germination of maize seeds stored in the earthen pots, PICS bag, and Jute bags were statistically similar. The traditional storage structures are equally effective for the maintenance of seed quality of maize.

Keywords: seed quality, vigor index, Jute bag, PICS bag, earthen pots, maize seed.

Correct citation: Marahatta, S. (2021). Assessment of the effectiveness of storage structures for maintaining the quality of maize seed stored at different moisture levels. *Journal of Agriculture and Natural Resources*, *4*(1), 96-110.
DOI: https://doi.org/10.3126/janr.v4i1.33231

INTRODUCTION

Maize (*Zea mays* L.) is the second most important crop of Nepal after rice in terms of both area cultivation and production (KC *et al.*, 2015). The national average yield of maize (2.35 t ha^{-1}) (MOF, 2017) is far below than the attainable yield of >8.0 t ha^{-1} (Devkota *et al.*, 2016). Current

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maize production of 1.3 million tons is not sufficient to meet the national demand thus yields of maize should be increased by 57% (CBS, 2014; MOF, 2017; TrendEconomy, 2020). The feed demand is increasing at 11% per annum, demands a huge amount of maize. As the possibility of expanding the area in the future is very limited, the required extra production has to come through an increase in productivity. Under the declining water, labor and increasing cost of production meeting such targets are challenging. Besides, farmers still face problems for retaining the quality of their produced seed from one farming season/year to another. Lack of sufficient quantities of quality seeds threatens the long-term sustainability of cereals production in the country (Tripathi *et al.*, 2018).

Seed is the principle factor that greatly affects the production and productivity of crop (Shrestha & Shrestha, 2017).Quality seed is considered as the basic, critical, and cheapest input for enhancing productivity and increasing higher net monetary returns per unit area (Hemming *et al.*, 2018).Investment in other costly inputs such as fertilizer irrigation, plant protection will not be remunerative without the use of the quality seed. Inappropriate storage conditions such as seed moisture and storage structures often result in low seed germination, seed deterioration, and loss of viability (Bhandari *et al.*, 2018). The loss of viability of seeds also associate with genetic damage (Pradhan & Badola, 2012) and the degree of damage depends on seed storage condition (Santos *et al.*, 2016). This leads to the deterioration of the seeds (Chhabra *et al.*, 2019). Proper storage conditions, however, may effectively retain substantial viability in seeds over a considerable storage period (Chen *et al.*,2007; Pradhan & Badola, 2008).

The quality of seed used for planting is the most influential factor that affects plant establishment and field population density (CABI, 2014), which is one of the major production problems of lower maize production in Nepal. In Nepal, most farmers fulfilled their seed demand from informal sources (Devkota *et al.*, 2018). Almost all seeds on the farmhouse are string on earthen pots and gunny bags (Thapa, 2006). In course of the storage, seed quality greatly deteriorates due to the condition of the stored seeds (Ali *et al.*, 2018). Most of these factors are influenced by packaging type and storage duration. Farmers commonly use saved seeds for the upcoming season, without testing. Thus, appropriate packaging materials/structures can maintain the seed quality for the next cropping. The use of hermetically sealed bags such as Super Grain bags (SGB) and Purdue Improved Crop Storage (PICS) bags have been reported as alternative storage options to maintain the quality of stored seeds for many crops in Africa and South Asia (Afzal *et al.*, 2017). Thus, an experiment was done to assess the influence of traditional as well as the modern packing materials/structures on the seed quality maintenance of maize, stored under different moisture levels so that appropriate storage structures could be suggested for ordinary farmers.

MATERIALS AND METHODS

Study site

The study was performed at the Central Seed Testing Laboratory (CSTL) of Seed Quality Control Center (SQCC) (http://sqcc.gov.np/en) from Hariharbhawan, Lalitpur (altitude of 800 m), Nepal from November 2017 to June 2018. The average relative humidity, the minimum and maximum temperature of the room recorded over the storage period with a temperature/humidity data logger was 51.87%, 11.95, and 21.36°C, respectively (Fig. 1). The seeds were obtained from the National Maize Research Program (NMRP), Rampur, Chitwan,

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Nepal (nmrp.gov.np) (altitude of 228 m), respectively, and seeds were collected one month after harvesting.

Experimental details and treatments

The experiment was set up in the storage room of CSTL, SQCC. The experimental design was a factorial complete randomized design including two moisture levels (12 ± 0.15% and 13.5 ± 0.18%) and 4 storage structures/materials {(metal bin (25 kg capacity), earthen pot (20 kg capacity), Purdue Improved Crop Storage (PICS) bag (50 kg capacity), and jute bag (30 kg capacity)} both. Two bags/structures/materials per storage structure/materials were used for each moisture level (a total of 16 bags for each crop). Twenty kg of seed was stored in each storage structure/material. The seed used was Rampur, Composite (a popular maize variety for Terai and inner Terai). Before storage, the seeds were dried down to the required moisture levels and then cleaned by removing all the broken seeds and other inert material. The storage duration was eight months (2017 November - 2018 June).

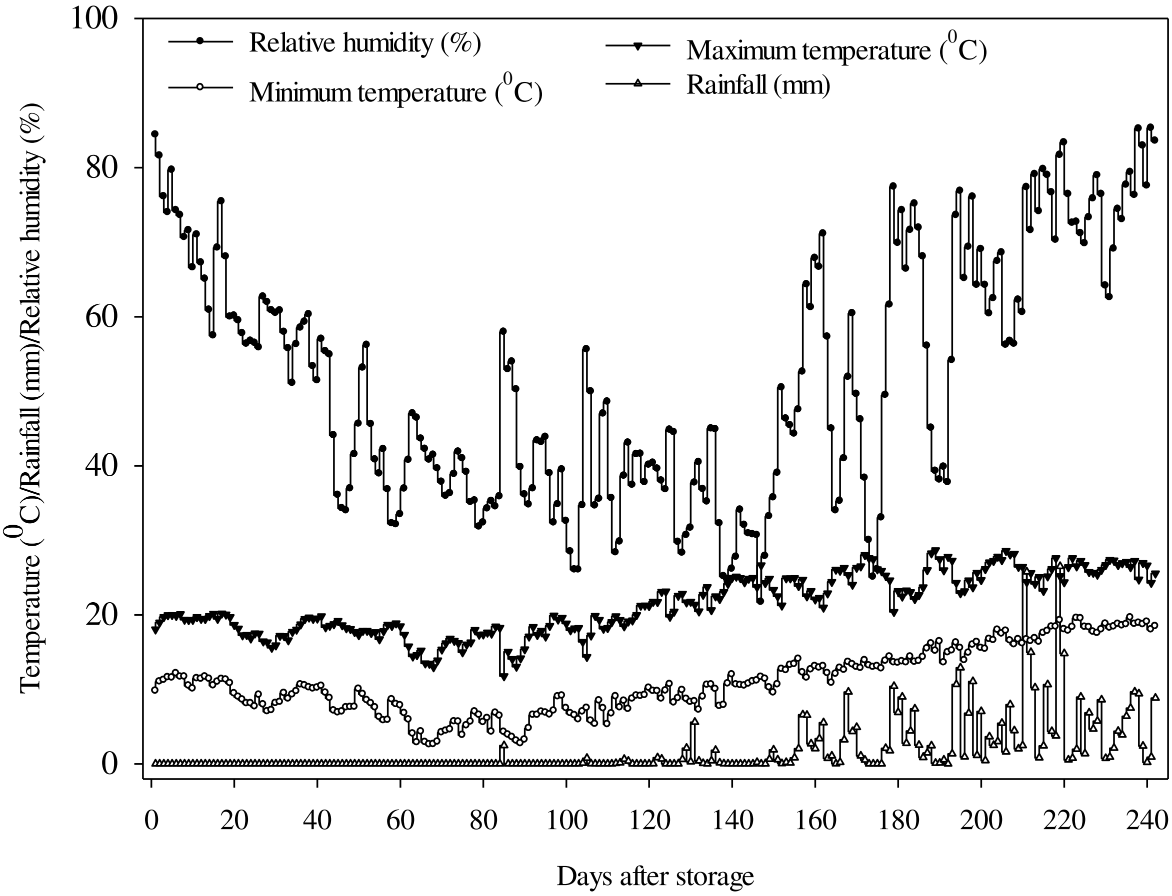

Figure 1. Daily maximum and minimum temperature, relative humidity, and rainfall at Central Seed Testing Laboratory (CSTL), Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur (2017 November to 2018 June)

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Seed sampling and data collection

The seed for quality analysis was collected from the storage bags every two months during the trial period (up to eight-month). After the sample collection, the storage materials/structure was again shielded. At each data observation date, 1.0 kg of seed samples were taken out and seed moisture content, germination percentage, seedling shoots, roots length, and vigor index were tested.

Seed moisture content was determined on ground samples by the high constant temperature oven method (130ºC ± 3ºC) for 2 and four hours (International Seed Testing Association (ISTA) rule 2012) and was expressed on a wet weight basis. Four hundred pure seeds in each observation date were tested for germination. A hundred seeds were rolled on moist paper towels (250 grams per square meter) and then kept at 25°C in CSTL, SQCC according to ISTA rules 2012, and two counts were done. The first count was done in 5 days and the final or the second count is done in 8 days for maize. In the first count, the normal seedlings are removed, counted, and recorded from each replicate. Badly decayed seedlings were also removed to use the secondary infection, counted, and recorded. At last, abnormal seedlings with other defects, insufficiently developed seedlings, and non-germinated seeds were left on the substrate and placed back in the germinator until the final count. In the final count, the normal seedlings, abnormal seedlings, and non-germinated seeds (dead and decay seed) were counted and recorded. The results of the germination test were calculated as the average of four replicates of 100 seeds. It was expressed as a percentage by the number of normal seedlings. For the seedlings' shoot and root length, a total of 25 seeds of germination test were used. The length of shoot and roots were measured from the normal germinated seeds of the first count. Seed vigor index is calculated by multiplying germination (%) and seedling length (mm) (Abdul-Baki & Anderson, 1973).

Dependent variables were subjected to analysis of variance using the RStudio of R version 3.6 .1 for two-factor CRD and Duncan's Multiple Range Test (DMRT) for mean separations (Go mez & Gomez, 1984). Treatments differences were considered statistically significant at 0.05 levels of significance (Shrestha, 2019). Sigma Plot v. 7 was used for the graphical presentatio n.

RESULTS

Influence of seed moisture and storage materials/structure on seed moisture content

The influence of initial seed moisture percentage on the seed moisture content during storage was significant for storage days up to 180 days (Table 1). The seed moisture content was significantly ($p<0.05$) higher for the seed stored at a higher moisture level. Storage types influenced the seed moisture at 120 and 180 DAS. The moisture content of seed stored at traditional structure/material (jute bag and earthen pot) was significantly ($p<0.05$) lower than the seed stored in PICS bag at both dates of observations whereas at par ($p>0.05$) with a metal bin at 180 DAS.

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Table 1. Influence of seed moisture levels and storage types on seed moisture content (%) of maize seed during storage at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015

Treatments	Seed moisture content (%)			
	60 DAS	120 DAS	180 DAS	240 DAS
Seed moisture content (%) during storage				
Seed moisture (12.0%)	12.97^{b}±0.06	12.73^{b}±0.09	13.17^{b}±0.21	13.61±0.36
Seed moisture (13.5%)	13.88^{a}±0.07	13.64^{a}±0.24	13.90^{a}±0.24	14.08±0.24
LSD (=0.05)	0.15	0.25	0.54	0.84
F- probability	<0.001	<0.001	0.010	ns
Seed storage types				
Jute bag	13.38±0.12	12.50^{c}±0.16	13.10^{b}±0.42	13.56±0.68
PICS bag	13.46±0.28	13.63^{a}±0.38	14.13^{a}±0.28	14.60±0.25
Metal bin	13.46±0.27	13.57^{a}±0.30	13.81^{ab}±0.36	13.96±0.38
Earthen pot	13.42±0.21	13.03^{b}±0.18	13.11^{b}±0.13	13.27±0.14
LSD (=0.05)	0.21	0.36	0.76	1.19
F-probability	ns	<0.001	0.023	ns
CV, %	3.86	5.88	6.34	7.76
Grand mean	13.43	13.18	13.54	13.85

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 0.05 level of significance; ns, non-significant.

The interactions of initial seed moisture percent and storage types on maize seed moisture content were significant ($p<0.05$) at 60, and 120 DAS (Fig. 2). The seed moisture content at 60 DAS was significantly ($p<0.05$) lower for the seed stored at higher seed moisture on jute bag as compared to PICS bag and metal bin whereas the seed stored at lower initial moisture on jute bag was significantly lower than the seed stored in PICS bag. The seed stored at higher initial seed moisture (13.5%) on all storage types were equally ($p>0.05$) effective for seed moisture content at 120 DAS whereas the seeds of lower initial seed moisture (12.0%) when stored on traditional storage materials had resulted significantly ($p<0.05$) lower seed moisture as compared to PICS bag and metal bin.

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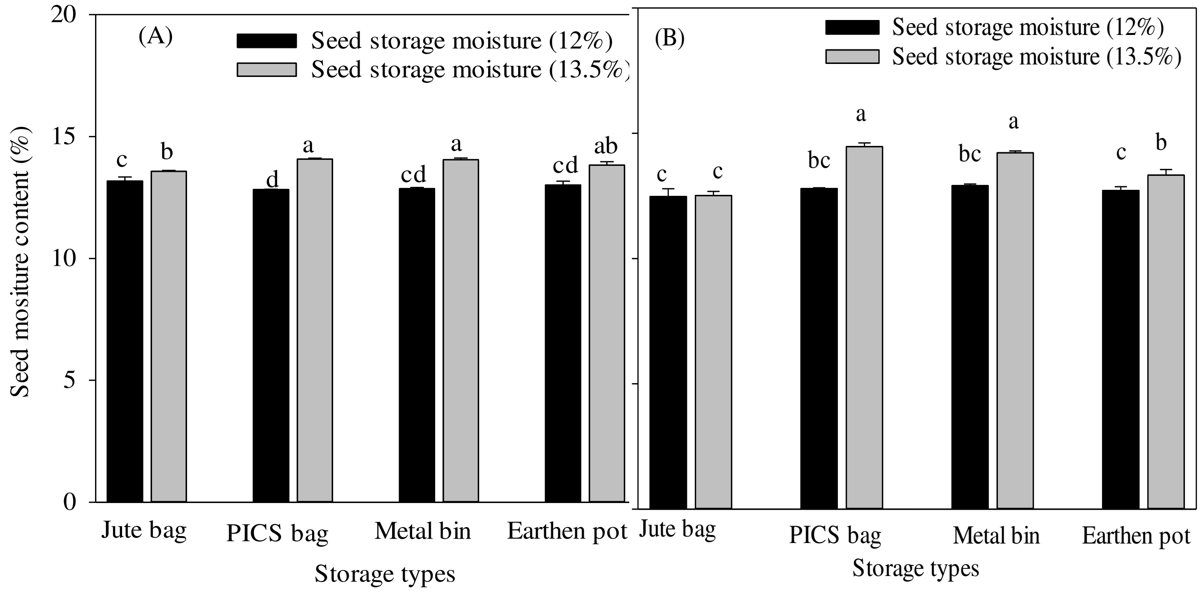

Figure 2. Interaction of seed moisture levels and storage types on seed moisture content (%) of maize seeds after 60 and 120 days after storage at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015

Note: Mean separated by DMRT and columns represented with the same letter (s) are non-significant at 0.05 level of significance; ns, non-significant.

Influence of seed moisture and seed storage type on seedling vigor

Both the root and shoot length were longer for initial observations but decreased as the storage duration increased. During initial observations, the longer root and shoot length of both crops were recorded from the seeds stored at higher seed moisture but was gradually shorter than the seed stored at lower moisture levels for later observations (Table 3). The lower initial seed moisture resulted in significantly longer ($p<0.05$) root at 180 and 240 DAS and shoot length at 180 DAS. The root length of maize seedlings was statistically similar ($p>0.05$) among seeds stored in jute bags, metal bin, and earthen pots but significantly ($p<0.05$) longer than the seedlings' roots of seeds stored on PICS bags at 180 DAS (Table 3). Similarly, the shoot length was significantly ($p<0.05$) longer when the seed was stored in the jute bags than the seeds stored in other types of storage at 180 DAS, and the significantly ($p<0.05$) shorter shoot length was recorded from the seeds stored in PICS bags. At 240 DAS, the shoot length was significantly ($p<0.05$) longer when the seed was stored in the jute bags than the seeds stored in PICS bag at par ($p>0.05$) with the seeds stored in the earthen pot

Figures 3 depicted the interaction effect of seed moisture and storage type on seeding root and shoot length. Seed moisture levels at the time of storage had significantly influenced the seedlings root length when stored in PICS bag and metal bin whereas in the traditional storage materials/types the initial seed moisture levels had no effect on the seed moisture at the 120 DAS (Fig. 3A) whereas at 180 DAS, lower seed moisture levels at the time of storage had resulted in significantly longer the seedlings shoot length at 120 DAS and root length at 180 DAS when stored in PICS bag, metal bin and jute bag but seedlings root length was influenced by the interactions for the earthen pot (Fig. 3B and 3C).

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Table 3. Influence of seed moisture levels and storage types on root length (mm) in maize seeds during storage at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015

Treatments	Root length (mm)				Shoot length (mm)			
	60 DAS	120 DAS	180 DAS	240 DAS	60 DAS	120 DAS	180 DAS	240 DAS
Seed moisture content (%) during storage								
Seed moisture (12.0%)	1.12±0.01 (12.35)	1.08±0.03 (11.171)	0.97^{a}±0.04 (8.75)	0.58^{a}±0.11 (5.39)	12.48 ±0.28	1.10±0.03 (11.73)	1.00^{a}±0.04 (9.38)	0.51±0.10 (4.06)
Seed moisture (13.5%)	1.13±0.02 (12.73)	1.04±0.02 (10.19)	0.70^{b}±0.10 (5.29)	0.36^{b}±0.10 (2.7)	12.46 ±0.41	1.05±0.02 (10.33)	0.72^{b}±0.09 (5.33)	0.36±0.10 (2.97)
LSD (=0.05)	0.04	0.07	0.08	0.11	1.07	0.05	0.16	0.12
F-probability	ns	ns	<0.001	0.005	ns	ns	<0.001	ns
Seed storage types								
Jute bag	1.15±0.01 (13.25)	1.07±0.05 (11.25)	1.01^{a}±0.04 (9.58)	0.79±0.04 (5.33)	12.83 ±0.50	1.08±0.05 (11.33)	1.03^{a}±0.06 (10.04)	0.74^{a} ±0.03 (4.54)
PICS bag	1.13±0.01 (12.46)	1.08±0.04 (11.21)	0.91^{a}±0.08 (7.88)	0.40±0.17 (3.00)	12.42 ±0.55	1.09±0.03 (11.42)	0.87^{b}±0.11 (7.58)	0.36^{b} ±0.14 (2.50)
Metal bin	1.14±0.02 (12.75)	1.02±0.03 (9.50)	0.47^{b}±0.15 (2.88)	N/A	12.46 ±0.37	1.05±0.03 (10.29)	0.62^{c}±0.15 (4.25)	N/A
Earthen pot	1.10±0.02 (11.71)	1.06±0.03 (10.75)	0.93^{a}±0.04 (7.75)	1.69±0.03 (3.92)	12.17 ±0.60	1.08±0.03 (11.08)	0.93^{b}±0.03 (7.54)	0.64^{ab} ±0.04 (3.42)
LSD (=0.05)	0.05	0.11	0.16	0.08	1.52	0.08	0.22	0.17
F-probability	ns	ns	<0.001	Ns	ns	ns	<0.001	<0.001
CV, %	3.90	8.39	35.61	29.7	9.56	7.98	31.61	22.27
Grand mean	12.54	10.68	7.02	3.00	12.47	11.03	7.35	3.54

Note: Initial root length at 12.0% moisture = 15.25 mm; initial root length at 13.5% moisture = 16.50; initial root length for storage type = 15.88 mm; initial shoot length at 12.0% moisture = 17.25 mm; initial shoot length at 13.5% moisture = 17.25 mm; initial shoot length for storage type = 17.25 mm. DAS, days after storage. Mean separated by DMRT and columns represented with same letter (s) are non-significant at 0.05 level of significance; ns, non significant. Figure in the parenthesis are the original value of the respective treatments while outside the parenthesis are log transformed value, log10(x+1).

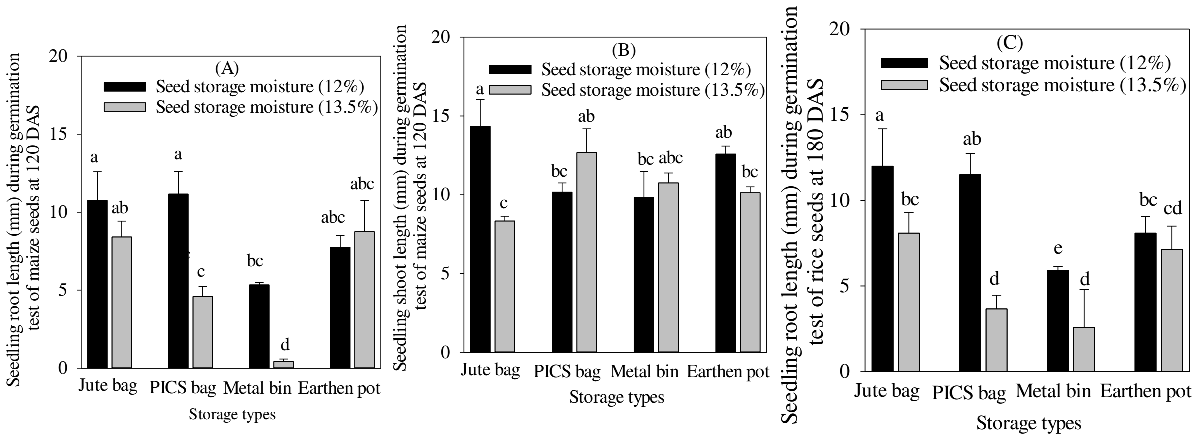

Figure 3. Interaction of seed moisture levels and storage types (A) seedling root length (mm) at 180 (B) seedling shoot length (mm) at 120 DAS, and (C) seedling shoot length (mm) at 180 DAS of maize during germination test at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015. Note: Means were separated by DMRT and same letter (s) in each group of bar graph represents non-significant at 0.05 level of significance; ns, non-significant; DAS, days after storage

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The vigor index was higher when the moisture content of the seeds at the time storage was lower and significant ($p<0.05$) only at 120-240 DAS (Fig. 4A). The vigor index of seeds was not significant by the storage types except at 180 DAS (Fig. 4B). At 180 DAS, the vigor index of seeds stored in jute and PICS bags had resulted in the significantly ($p<0.05$) higher than stored in a metal bin and statistically at par with the seed stored in the earthen pot.

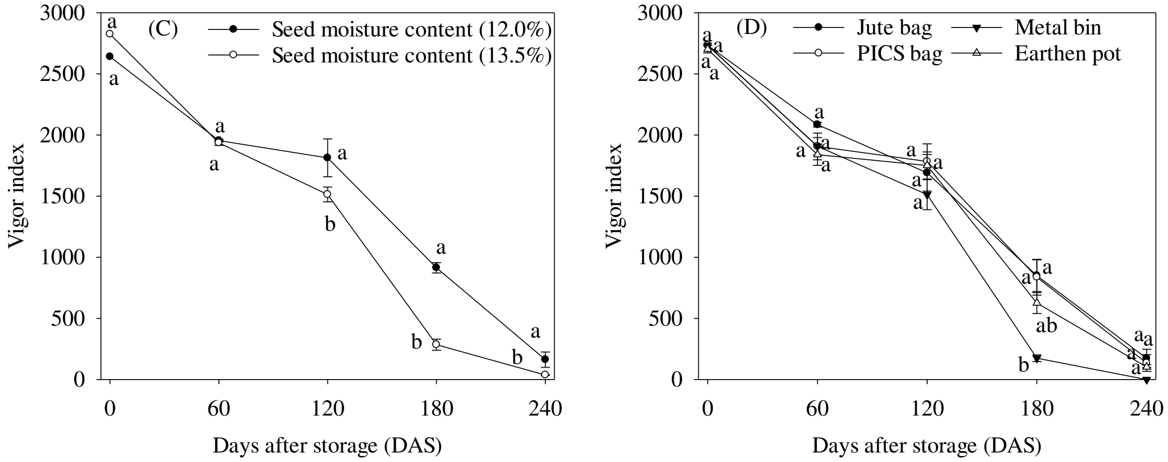

Table 4. Influence of seed moisture levels and storage types on vigor index of rice and maize seeds during storage at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015

Note: Means were separated by DMRT and same letter (s) in a line graph represent non-significant at 0.05 level of significance

Influence of seed moisture levels and seed storage types on germination percentage

The trend showed the decreasing germination percentage against the storage duration but the drastic deterioration was recorded for the maize seeds (Table 4). The seed moisture content at the time of storage significantly affected the germination percentage at 120-240 DAS. In these observations significantly ($p<0.05$) higher germination percentage was observed when the seed moisture content at the time of storage was lower. The storage types significantly ($p<0.05$) affected the germination percentage only at 120 and 180 for maize seeds. Seed stored in traditional materials/structure (jute bags and earthen pot) had significantly ($p<0.05$) lower germination percentage at 120 DAS than the seed stored in PICS bag but at 180 DAS germination percentage of seeds stored in these traditional materials/structure was statistically at par ($p>0.05$) with the seed store in PICS bag.

The abnormal seedling percentage was found to be influenced ($p<0.05$) by seed moisture content for only up to 120 DAS (Fig. 8). At the initial reading, maize seeds stored in 12.0% moisture content had higher ($p<0.05$) abnormal seedling percentage which reversed for the 60 and 120 DAS with higher ($p<0.05$) abnormal seedling percentage on the seeds stored at 13.5% moisture level. For storage types, the abnormal seedling percentage was observed significant ($p<0.05$) at 120 DAS and there afterward. Significantly ($p<0.05$) lower abnormal seedlings were observed from the seeds stored in PICS bags while at 180 DAS it was statistically at par ($p>0.05$) with the seeds stored in a metal bin.

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Table 4: Influence of seed moisture levels and storage types on germination percentage in rice and maize seeds during storage at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015

Treatments	Maize			
	60 DAS	120 DAS	180 DAS	240 DAS
Seed moisture content (%) during storage				
Seed moisture (12.0%)	78.71±0.87	79.63^{a}±0.75	6.78^{a} ±0.40 (47.17)	3.80^{a} ±0.68 (25.31)
Seed moisture (13.5%)	76.56±1.05	73.02^{b}±1.16	4.31^{b} ±0.52 (21.06)	1.99^{b} ±0.30 (8.00)
LSD (=0.05)	2.73	2.50	0.78	1.11
F-probability	ns	<0.001	<0.001	0.015
Seed storage types				
Jute bag	79.96±1.09	74.25^{b}±1.95	6.34^{a}±0.49 (40.88)	3.72±0.84 (18.9)
PICS bag	76.42±1.81	79.33^{a}±1.28	6.58^{a}±0.74 (45.54)	3.86±1.00 (19.46)
Metal bin	75.71±1.08	76.92^{ab}±1.99	3.50^{b}±0.93 (16.00)	-
Earthen pot	78.46±1.13	74.79^{b}±2.13	5.76^{a}± 0.53 (34.04)	3.29±0.48 (11.50)
LSD (=0.05)	3.87	3.53	1.10	1.57
F-probability	ns	0.031	0.003	ns
CV, %	4.45	6.19	36.30	38.90
Grand mean	77.64	76.32	34.11	15.96

Note: Initial germination percentage at 12.0% moisture = 81.25; initial germination percentage at 13.5% moisture = 82.50; initial germination percentage for storage type = 81.88. DAS, days after storage. Mean separated by DMRT and columns represented with the same letter (s) are non-significant at 5% level of significance; ns, non-significant. The figures in the parenthesis are the original value of the respective treatments while outside the parenthesis are log-transformed value, log10(x+1)

The dead seed percentage was influenced significantly ($p<0.05$) by seed moisture content at 120 and thereafter, where it was higher ($p<0.05$) for the seeds stored at initial seed moisture of 13.5%. The seed storage type only influenced ($p<0.05$) the dead seed percentage at 180 days, in which maize seeds in the metal bin had resulted in the significantly ($p<0.05$) higher dead seed whereas the seeds stored in jute bag had significantly ($p<0.05$) lower dead seed percentage than the seed stored in metal bin and PICS bag but at par ($p<0.05$) with the seeds stored in the earthen pot.

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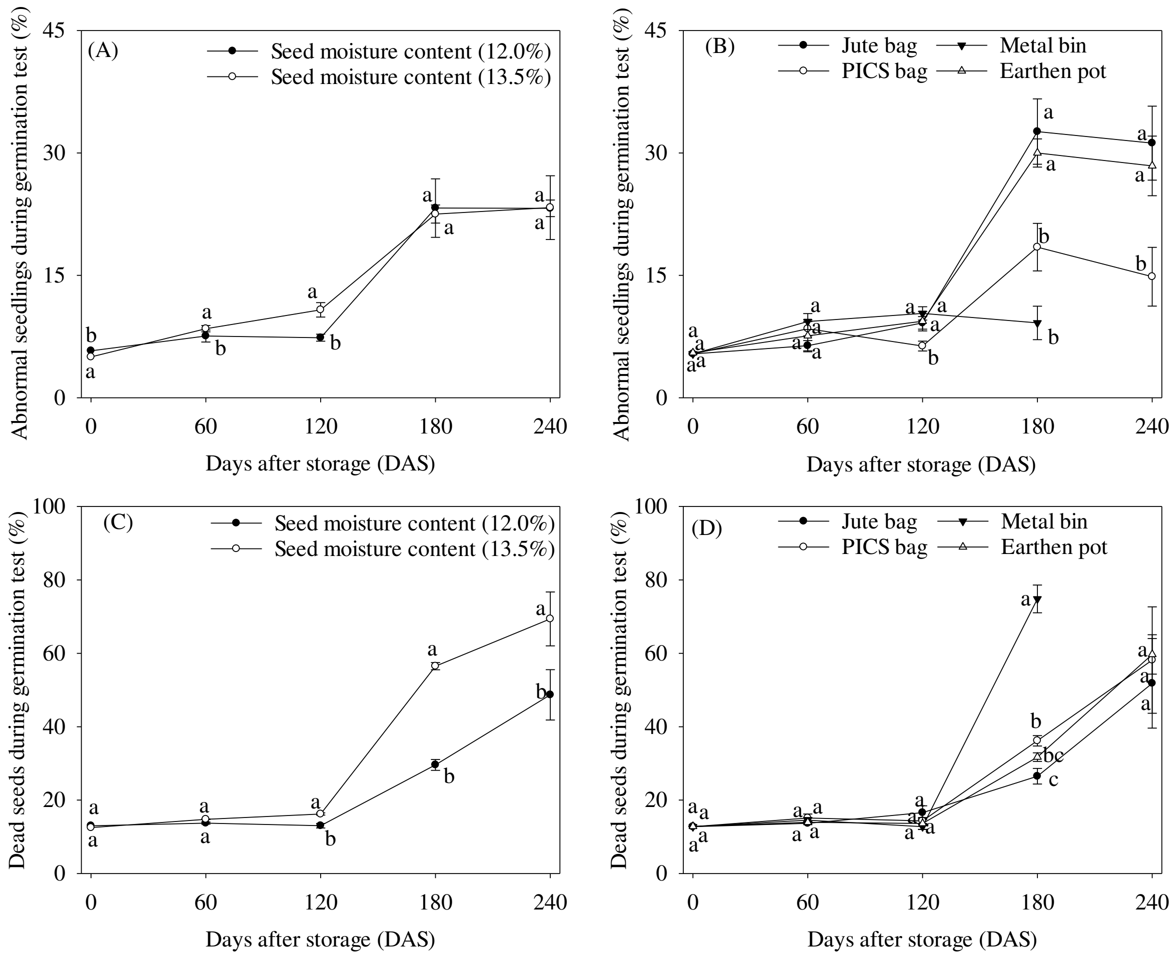

Figure 5. Abnormal seedlings percentage influence by (A) seed moisture at storage, and (B) storage types, dead seeds percentage influenced by (C) seed moisture at storage, and (D) storage types during germination test in maize seeds during storage at Seed Quality Control Center (SQCC), Hariharbhawan, Lalitpur, 2015

Note: Mean separated by DMRT and columns represented with the same letter (s) are non-significant at 0.05 level of significance.

DISCUSSION

Seed storage and seed quality

Seed deterioration during the storage period was due to the damage in membrane, enzyme, proteins, and nucleic acid, besides, accumulation with time such degenerative changes result in complete disorganization of membranes and cell organelles and ultimately causing the death of the seed and loss of germination (Roberts, 1972). Moreover, prolonging the storage period with high seed moisture percentage significantly reduction in storage efficiency (infested seeds, damage grains percentage, grains weight loss percentage), germination characters, seed viability, and quality (Attia *et al.*, 2015; Naguib *et al.*, 2011; Rao *et al.*, 2006). Raza *et al.* (2010) revealed that the storage duration of 12 months generally increased moisture and fat acidity, while decreased thousand grain weight.

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Effect of storage seed moisture levels on seed quality

Seed moisture plays a major role in seed storage. Seeds of different species have a difference in moisture-holding capacities and absorbing potentials. Higher seed moisture is injurious to seed life and rapidly reduces viability during storage. The biological activity, growth, and multiplication of insects and pathogens are greater at higher levels of moisture. Harrington (1972) stated that seed longevity decreases by one-half for every 1 percent rise in seed moisture and that it maintains well at the moisture range of 5 to 14 percent. Seed moisture varies in different species as a result of differences in the chemical composition of seeds and conditions prevailing during seed development and maturation. High-moisture seeds are more susceptible to heat damage. The rate of seed deterioration enhances with increased moisture levels. Seed moisture content fluctuates with long-term changes in atmospheric humidity.

Seed moisture of 5 to 7 percent is ideal for the safe storage of seeds in hermetic containers (Doijode, 2001). Cromarty *et al.* (1982) recommended seed drying at low temperature (15^{0}C) and low relative humidity (15%) for safe storage. Guanfhua (1994) reported that the ultra-drying of seeds improves seed storability. Ultra dry (2.0 to 3.7% moisture content) seeds preserve viability better than dry (5.5 to 6.8% moisture content) seeds at 20^{0}C (Ellis *et al.*, 1996). Seed moisture increases especially in sealed storage; therefore, well-dried and low-moisture seeds are preserved in moisture-proof containers during storage.

Effect of seed storage container types on seed quality

Seeds are stored in different containers to protect them from extraneous environmental factors, to facilitate easier handling during storage, and to enhance their marketability. Seeds should be suitably protected from high atmospheric humidity, and also from storage insects and pathogens. Normally, seeds are packed in cotton, jute, paper bags, polyethylene bags, laminated aluminum foil pouches, or aluminum cans. Low-moisture seeds should be packed in sealed packages. Doijode (2001) reported that seeds in unsealed containers deteriorated rapidly under high temperatures and humidity, whereas those in sealed containers maintained reasonably high viability. Seeds of many crops retained viability when stored in a metal bin, super grain bag, and PICS bag, etc. (Bhandari *et al.*, 2018). In sealed containers, dry seeds with 5-7% moisture content retained high germination both at low (-15 to 5^{0}C) and at high (25^{0}C) temperatures (Doijode, 2001).

In general, the moisture content decreased initially and then increased in PICS bags and metal bins while decreased in earthen pots and jute bags. The decrease in the moisture content of the stored seed was due to the increase in ambient temperature and a decrease in relative humidity (Fig.1). An increase in temperature and a decrease in relative humidity caused the drying of seeds especially in the jute bag and earthen pot due to high porosity. This was because there occurred rainfall beyond 120 days, which increased the relative humidity of the air and also lowered the temperature of the environment. This was due to the difference in moisture transmission capacity of the different storage structures. The structure wall having a higher water vapor transmission rate facilitated a higher increase or decrease in the moisture content of the stored seed. However, the reduction in moisture content was found to be only in jute bags and earthen pot whereas increased in PICS bag and metal bins at 60 DAS, then increment in seed also lower in the traditional storage types. In contrast, Nyaaba (2015) stated that seeds stored in woven unlined nylon sacks and unlined jute sacks increased in moisture content after

Journal of Agriculture and Natural Resources (2021) 4(1): 96-110
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v4i1.33231

storage. This could be due to the porous and pervious nature of the packaging material which allowed the seeds to absorb moisture from the environment.

The results of the present study indicate that the moisture content of seeds stored in different types of containers increased and root and shoot length, seed germination decreased while increased the abnormal seedlings and dead seeds at the time germination test with the progress of storage period. Seed deterioration and the ageing process are affected by genetic factors (Rai *et al.*, 2011). Chromosomal damages may be the prominent causes of reduced germination and other seedling characters as compared to control. The reduction in germination percentage might have been due to the effect of storage on meristematic tissues of the seed. Gutiérrez *et al.* (1993) while working on maize reported a significant reduction in germination, viability, root length, dry matter reduction, and vigor index with the response to a period of aging. Similar results were also obtained by Kumar and Rai (2007), and Rai *et al.* (2011).

Germination was significantly influenced by the containers for the later period of storage while the abnormal seedlings were not influenced by the storage containers. The normal seedling was decreased with the increase of storage period and the abnormal seedling was increased with the increase of storage period. The highest germination percentage was recorded in the earthen pot followed by jute bags while the lowest in the metal bins. The maximum abnormal seedling was recorded in PICS bags followed by the metal bin, earthen pots, and minimum in the jute bag. But Mali *et al.* (1983) reported that the increasing rate of abnormal seedling was higher in seeds of gunny bags because it was due to high moisture and fungal activities. Alam *et al.* (2009) found that the germination percentage of Boro rice seeds stored in the organic cocoon was significantly the highest compared to that of resin cocoon, polythene bag, polythene in a gunny bag and gunny bag.

Interaction storage type and seed moisture at storage on seed quality

Storage in the high moisture level in the PICS bag and the metal bin highly deteriorates the germination percentage and while increased the dead and abnormal seedlings. The earthen pots and jute bags gave higher germination capacity than the PICS bag and metal bin at the higher seed moisture content (%) during the long storage period may be due to quick moisture losses and available oxygen in these bags. These results are confirmed by Singh *et al.* (2000) who reported a 5-17% reduction in seed germination when the seed was stored approximately for five months, they further noted, that when seed stored in concrete bins, the seed germination was higher against metal bins.

CONCLUSION

The germination percentage, root, and shoot length are found to be higher in the seed moisture content at 12.0 percent moisture and jute and earthen container. Similarly, based on the storage period the moisture content of the seeds was also found to be lower for the seed stored with lower moisture content i.e. at 12.0 and stored in jute bags. Thus, for maintenance of the quality of seed, the seed should be stored at a moisture percent lower moisture and traditional storage materials/structure (jute bags and earthen pots) were equally effective to PICS bags and more effective than the metal bin.

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v4i1.33231

ACKNOWLEDGEMENT

This work was supported by the Directorate of Research and Extension (DOREx) of Agriculture and Forestry University (AFU), Rampur, Chitwan Nepal

Author's contribution

S. Marahatta conducted research and wrote this paper.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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