RESEARCH ARTICLE

Comparative study of seed quality parameters in four varieties of wheat stored in different packing materials

Sunita Bhandari, Sarita*, Ravi Kumar, Bankey Lal

Bhandari S, Sarita S, Kumar R, et al. Comparative study of seed quality parameters in four varieties of wheat stored in different packing materials. AGBIR.2023;39(6):716-722.

This comparative study investigates the impact of different packaging materials on seed quality parameters of four wheat varieties (VL-802, VL-829, VL-892, and UP-1109) during storage periods of 6, 12, and 18 months. Seed quality parameters included test weight, first count, moisture content, germination rate, root length, shoot length, weight of fresh seedlings, and weight of dry seedlings. Four packaging materials, namely cotton bag, plastic container, steel container, and earthen pot, were employed in a controlled storage environment. The study revealed significant variations in seed quality parameters due to storage materials, seed varieties and duration. Notably, steel container exhibited the best performance followed by plastic container and earthen pot for maintaining seed quality over time, while cotton bags performed the least favorably. Among all the verities VL-802 showed the highest seed quality parameters for maintaining the seed quality till the 18 month in case of 1000 seed weight and dry weight and minimum in VL-829. Seed moisture content, first count, shoot length, roots length and fresh seedling weight was highest in VL-892 and minimum in UP-1109. Standard germination was highest in VL-829 and lowest in UP-1109. Seed moisture content decreased as storage duration increased, seed vigor declined with longer storage periods, and the choice of packaging container significantly affected the first and standard germination count. Moreover, shoot and root lengths, as well as seedling fresh and dry weights, were found to vary with both storage container and wheat variety. These findings emphasize the importance of selecting appropriate storage containers and monitoring storage conditions to ensure the preservation of wheat seed quality.

Key Words: *Seed quality; Wheat seed verities; Packaging material; Storage period; Seed vigour*

INTRODUCTION

Wheat (*Triticum aestivum* L.) stands as a cornerstone of global agriculture, assuming a pivotal role in ensuring food security. This cereal crop serves as a dietary staple for countless individuals, contributing significantly to their daily caloric intake [1]. Wheat is a ubiquitous grain cultivated, consumed, and traded globally, ranking third among all cereals [2]. The fundamental units of crop production are the seeds and their quality exerts a profound influence on agricultural productivity. Preserving seed quality is essential to safeguard genetic integrity and enhance crop yield. Effective storage techniques are vital in preventing seed deterioration over time. The choice of storage containers or packaging materials plays a pivotal role in determining seed longevity during storage conditions [3]. Proper packaging should help curtail the deterioration process, maintaining the seed's original moisture content and averting respiration during storage [4]. Seed deterioration is closely linked to packaging container characteristics, impacting the ease of water vapor exchange between seeds and the atmosphere [5].

The primary objective of this study is to compare the impact of various packaging materials on the seed quality parameters of four wheat varieties VL-802, VL-829, VL-892 and UP-1109 during storage periods of 6, 12 and 18 months. The evaluated seed quality parameters encompass test weight, initial count, germination rate, moisture content, root shoot length, seedling fresh weight and seedling dry weight.

MATERIALS AND METHODS

Seeds from the four wheat varieties, namely VL-802, VL-829, VL-892 and UP-1109, were sourced from VCSG UUHF Uttarakhand, and subjected to rigorous purity and viability assessments. Four distinct types of packaging materials were selected for the storage experiment: Cotton bags, plastic containers, steel containers, and earthen pots. The experiment adhered to a Completely Randomized Design (CRD) with four replicates per treatment and variety. The seeds were stored under controlled conditions, maintaining a temperature of 20°C ± 2°C and a relative humidity of 50% ± 5% to mimic real-world storage conditions. The seed quality parameters were assessed at 6, 12 and 18 months of storage for each variety and packaging material like test weight, moisture content, initial count, standard germination rate, root length, shoot length, weight of fresh seedlings, and weight of dry seedlings. The present investigation was conducted at RNB global University at Bikaner, 2023 in genetics and plant breeding laboratory.

Seed weight (g) 1000

Seeds were dried and random sample of 1000 seeds were weighed on electronic balance in each treatment to get 1000 seeds weight.

Moisture content (%)

Seed moisture is determined by the air oven methods. In this method the seed moisture content is determined by removing the moisture from the seeds by the hot air oven.

First count test (%)

For the initial assessment, we conducted a first count test, which involved taking four replications of 25 seeds from each variety randomly selected from each treatment. These seeds were placed between paper (B.P.) media and were kept in a germinator at 25°C. The first count was recorded on the 4th day of the test.

Standard germination (%)

To determine standard germination percentage, we took 25 seeds from samples of each treatment for every variety, with four replications, and placed them between paper (B.P.) at 25°C. On the 8th day, we assessed the seedlings and counted the normal seedlings. The germination percentage was then calculated using the formula:

$$Ger\min ation\% = \frac{Normalseedling}{Tota\ln{.}\text{ofseed}} \times 100$$

Root length (cm)

On the 8th day of germination testing, we randomly selected five normal seedlings from each replication of each treatment and measured their root length in centimeters, calculating the mean root length.

Shoot length (cm)

The shoot length (in centimeters) was determined by measuring five randomly selected seedlings from each replication of each treatment, and the mean value was calculated.

School of Agriculture, RNB Global University, Bikaner-334601, Rajasthan, India

Correspondence: *Sarita, School of Agriculture, RNB Global University, Bikaner-334601, Rajasthan, India, E-mail: sharmasarita499@gmil.com*

Received: 01-Nov-2023, Manuscript No. AGBIR-23-122047; **Editor assigned:** 03-Nov-2023, Pre QC No. AGBIR-23-122047 (PQ); **Reviewed:** 22-Nov-2023, QC No. AGBIR-23-122047; **Revised:** 29-Nov-2023, Manuscript No. AGBIR-23-122047 (R); **Published:** 06-Dec-2023, DOI:10.35248/0970-1907.23.39.716-722

Seedling fresh weight (g)

On the 8th day of germination testing, we randomly selected five normal seedlings from each replication of each treatment and weighed them using an electronic balance in grams.

Dry weight (g)

The seedling dry weight was recorded on the 8th day of germination testing. Five normal seedlings were randomly chosen from each replication of each treatment, and these seedlings were dried in an oven at 80°C for 24 hours. The dried seedlings were then weighed using an electronic balance and expressed in grams.

RESULTS AND DISCUSSION

The data collected from the assessment of seed quality parameters underwent rigorous statistical analysis. These results were then utilized to ascertain significant distinctions between various treatments and storage periods for each seed variety and packaging material. The subsequent discussion will focus on how different packaging materials impact seed quality parameters and how each seed variety behaves during prolonged storage.

The study involved evaluating the 1000-seed weight (TSW) of different wheat varieties across various storage containers over three distinct time intervals: 6 months, 12 months and 18 months. Additionally, it presents the means and Critical Differences (CD) at a 1% significance level for both the variety and container factors. The Analysis of Variance (ANOVA) revealed a significant ($P<0.01$) interaction effect between storage periods and materials, which notably influenced the TSW of wheat varieties (Table 1). The study identified significant variations in TSW among different wheat varieties stored in various storage materials and durations. The TSW exhibited a decrease as storage time extended, presumably due to seed damage, resulting in reduced seed weight [6]. Prolonged storage consistently led to a reduction in the 1000-seed weight for all four wheat varieties across all storage containers. At the 6-month, 12-month, and 18-month marks, steel containers exhibited the highest mean values (44.23 g), followed by earthen pots, plastic containers, and cotton bags (Table 1). Notably, the interaction between varieties and containers exhibited significant variation. The results indicate that the highest 1000-seed weight was recorded for the combination of the VL-892 variety stored in a steel container, while the lowest weight was observed for the VL-829 variety stored in a cotton bag. A similar trend, where increasing storage duration significantly decreased the TSW of barley stored in various containers also reported [7,8]. The most significant alterations in wheat quality when it was stored in gunny bags, as opposed to metal bins [9]. It's important to note that all packing materials, with the exception of metal and earthen bins, exhibit high levels of porosity. Consequently, the utilization of bins effectively mitigated grain weight loss during the storage period.

The moisture content (%) data for wheat stored in various types of containers, including cotton bags, plastic containers, steel containers, and earthen pots, was examined in relation to four different wheat varieties (VL-802, VL-829, VL-892 and UP-1109) over different storage periods (6 months, 12 months, and 18 months). The provided values in the table represent mean along with Standard Errors (SE) and the Critical Difference (CD) at a 1% significance level for both variety and container effects. It's important to note that seed moisture content plays a pivotal role in determining the longevity of stored seeds. Higher seed moisture content tends to accelerate seed deterioration, ultimately compromising seed quality [10].

The data from this study reveals a consistent trend: moisture content in wheat varieties decreased as the storage duration increased across all storage materials (Table 2). Specifically, after 18 months of storage, the increase in moisture content of wheat varieties was ranked as follows: steel containers, plastic containers, earthen pots, with cotton bags having the lowest moisture content. Additionally, VL-892 exhibited the lowest moisture content, followed by VL-829, VL-802 and UP-1109 varieties. Notably, seeds stored in earthen pots and jute sacks experienced a greater increase in moisture content, likely due to their exposure to air [11]. It's worth mentioning that regardless of the storage material, moisture content of the seeds gradually increased with longer storage periods [12,13]. Furthermore, after 18 months of storage, both variety and storage container were found to significantly influence moisture content. These findings underscore the substantial influence of both wheat variety and storage container on the moisture content of stored wheat. Researchers and wheat storage managers should carefully consider these factors when determining optimal storage conditions to preserve the quality of wheat over time.

TABLE 1

Effect of packaging container on the 1000 seed weight (gm) of wheat varieties

Container	Variety				Mean	SE±	CD (1%)
	1000 seed weight after 6 month						
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	42.69	39.48	45.41	40.31	41.97	0.31^{v}	1.20^{v}
Plastic cont.	45.44	38.88	41.27	42.41	42	0.31^{c}	1.20^{c}
Steel cont.	45.35	42.17	46.85	42.56	44.23	0.62^{vxc}	2.41^{vxc}
Earthen pot	42.49	41.72	43	42.41	42.4		
Mean	43.99	40.56	44.13	41.92	42.65		
	1000 seed weight after 12 month						
Cotton bag	40.93	39.27	41.4	40.71	40.58	0.20^{v}	0.79^{v}
Plastic cont.	39.15	37.46	44.05	40.58	40.31	0.20^{c}	0.79^{c}
Steel cont.	45.16	40.27	40.92	42.41	42.19	0.41^{vxc}	1.59^{vxc}
Earthen pot	41.98	38.34	42.1	39.33	40.44		
Mean	41.8	38.83	42.12	40.76	40.88		
	1000 seed weight after 18 month						
Cotton bag	39.46	38.81	37.94	38.64	38.71	0.20^{v}	0.78^{v}
Plastic cont.	43.03	36.73	37.39	37.61	38.69	0.20^{c}	0.78^{c}
Steel cont.	39.2	39.06	43.45	40.58	40.57	0.40^{vxc}	1.57^{vxc}
Earthen pot	41.43	38.14	43.45	38.59	40.4		
Mean	40.78	38.18	40.55	38.85	39.59		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

TABLE 2

Effect of packaging container on the moisture content (%) of wheat varieties

Container	Variety				Mean	SE ±	CD (1%)
	Moisture content after 6 month						
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	15.21	14.37	14.03	16.1	14.93	0.16^v	0.64^v
Plastic cont.	14.04	13.41	12.42	14.11	13.49	0.16^c	0.64^c
Steel cont.	12.24	11.13	10.26	14.11	11.93	0.33$^{v×c}$	0.1.28$^{v×c}$
Earthen pot	13.13	11.4	11.25	14.88	12.66		
Mean	13.65	12.57	11.99	14.8	13.25		
	Moisture content after 12 month						
Cotton bag	16.31	15.92	15.12	16.85	16.05	0.17^v	0.68^v
Plastic cont.	15.19	13.89	13.78	16.41	14.82	0.17^c	0.68^c
Steel cont.	14.4	12.3	13.11	15.55	13.84	0.35$^{v×c}$	1.37$^{v×c}$
Earthen pot	15.01	12.75	13.49	16.28	14.38		
Mean	15.23	13.71	13.87	16.27	14.77		
	Moisture content after 18 month						
Cotton bag	17.16	17.8	17.06	18.1	17.53	0.15^v	0.59^v
Plastic cont.	16.98	15.62	15.39	16.9	16.22	0.15^c	0.59^c
Steel cont.	16.21	15.86	14.6	16.55	15.81	0.30$^{v×c}$	1.19$^{v×c}$
Earthen pot	16.8	16.24	15.64	16.94	16.4		
Mean	16.79	16.38	15.67	17.12	16.49		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

The impact of various packaging containers on the first count of wheat seeds at different time intervals (6 months, 12 months, and 18 months) showed in Table 3. The data is expressed in terms of mean values, Standard Errors (SE), and Critical Differences (CD) at a 1% significance level. The highest vigor percentage was observed in seeds stored in steel containers, followed by those in plastic containers, earthen pots, and cotton bags. Among the different wheat varieties, VL-892 exhibited the highest vigor percentage, followed by VL-829, VL-802, and UP-1109, across all storage periods. The findings reveal a decrease in seed vigor as the storage period increases for each type of storage container and wheat variety. This outcome aligns with previous research by Naguib et al., [14] and Yaja et al., [15], which reported that seeds tend to lose their performance potential and vigor during storage before any decline in viability.

These results offer valuable insights into the influence of packaging containers on the first count of wheat seeds over time. It is evident that steel containers consistently yield higher mean first counts when compared to other containers, and the CD values underscore the statistical significance of these differences. Additionally, the data illustrates how the first count rate of wheat seeds changes with time for each container and wheat variety.

The impact of different packaging containers on the standard germination of wheat across three time intervals: 6 months, 12 months, and 18 months (Table 4). This germination rate is a crucial indicator of seed viability, as noted by Akter et al., [16].

After 6 month of storage cotton bag showed the lowest mean value of standard germination (72.66%) and steel container showed the highest mean value (85.66%) after 12 month of storage cotton bags displayed a mean germination rate of 69.33%. Plastic containers had a mean germination rate of 77.83%, steel containers exhibited a mean germination rate of 77.83% and earthen pots had a mean germination rate of 68.00%. and after 18 month of storage. Cotton bags showed a mean germination rate of 64.33%, plastic containers had a mean germination rate of 73.50%, steel containers exhibited a mean germination rate of 72.50% and Earthen pots had a mean germination rate of 58.25%. Significant differences were observed between the packaging containers ($p<0.01$) and storage durations ($p<0.01$). Notably, steel containers consistently outperformed the other containers in preserving seed germination, particularly after 18 months of storage. The influence of storage materials on wheat seed germination capacity during the storage period under study Seadh et al., [17].

The decline in germination percentage in earthen pots, caused by the high moisture content of the seeds, occurred more rapidly when compared to tin containers and plastic pots with seeds possessing lower moisture content [16]. Furthermore, an increase in moisture content of wheat seeds stored in permeable containers led to lower germination percentages in contrast to sealed storage, which maintained an entirely airtight environment.

It is evident that the choice of packaging container significantly affects the standard germination of wheat, with this effect being contingent on both the duration of storage and the specific wheat variety.

The impact of different types of containers (Cotton bag, Plastic container, Steel container and earthen pot) on the shoot length of various wheat varieties at three different time intervals: 6, 12, and 18 months (Table 5). The values in the table represent the average shoot length in centimeters, along with the Standard Error of the mean (SE±) and the Critical Difference (CD) at a 1% significance level. It's worth noting that the mean shoot length for all wheat varieties ranged from 5.37 to 8.26 cm after 6 months, from 3.78 to 7.74 cm after 12 months, and from 2.14 to 5.01 cm after 18 months. This observation aligns with the findings of Anonymous [18], indicating that high seed moisture levels can lead to increased seed respiration and reduced seed quality, resulting in weaker or abnormal seedlings. In most cases, the height of coriander seedlings was highest when stored in tin containers compared to polyethylene and jute bags [19]. Regardless of the storage container, the length of seedling shoots and roots decreased over time in all observed instances.

Interestingly, Steel containers initially show higher shoot lengths after 6 months for certain wheat varieties, but this effect diminishes over time (12 and 18 months). In contrast, earthen pots consistently exhibit favorable shoot lengths across all time points for most varieties. Plastic containers, on the other hand, yield variable results across different wheat varieties and time intervals. Cotton bags generally result in lower shoot lengths compared to the other container types. Seedling shoot and root length decrease over time regardless of the storage container used [20].

TABLE 3

Effect of packaging container on the first count (%) of wheat varieties

Container	Variety: First count after 6 month				Mean	SE ±	CD (1%)
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	62.66	74.66	80.66	58.33	69.08	0.43^{v}	1.67^{v}
Plastic cont.	66	77.33	82.33	65.33	72.75	0.43^{c}	1.67^{c}
Steel cont.	73	84.66	85.33	78	80.25	$0.086^{v\times c}$	$3.35^{v\times c}$
Earthen pot	69.33	80.66	84	73.33	76.83		
Mean	67.75	79.33	83.08	68.75	74.72		
	First count after 12 month						
Cotton bag	51.33	72	74.66	55.33	63.16	0.47^{v}	1.85^{v}
Plastic cont.	59.33	75.33	76.66	62	68.16	0.47^{c}	1.85^{c}
Steel cont.	69.33	79.33	80.66	73.33	75.66	0.95v×c	$3.75^{v\times c}$
Earthen pot	65.33	72.66	77.33	68.66	71		
Mean	61.33	74.83	77	64.83	69.5		
	First count after 18 month						
Cotton bag	47.33	66.66	68.66	50.66	58.33	0.39^{v}	1.54^{v}
Plastic cont.	56.66	68.66	70.66	54.66	62.66	0.39^{c}	1.54^{c}
Steel cont.	65.33	74	72	63.33	68.83	$0.79^{v\times c}$	$3.09^{v\times c}$
Earthen pot	61.33	69.33	70.66	58.66	64.83		
Mean	57.66	69.66	70.5	56.83	63.66		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

TABLE 4

Effect of packaging container on standard germination (%) on wheat varieties

Container	Variety: Germination after 6 month				Mean	SE ±	CD (1%)
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	68.66	78.66	83.33	62.66	73.33	0.33^{v}	1.29^{v}
Plastic cont.	69.33	80.66	85.33	69.33	76.16	0.33^{c}	1.29^{c}
Steel cont.	77.33	86.66	87.33	79.33	82.66	$0.66^{v\times c}$	$2.58^{v\times c}$
Earthen pot	75.33	82.66	86.66	77.33	80.5		
Mean	72.66	82.16	85.66	72.16	78.16		
	Germination after 12 month						
Cotton bag	64.66	74.66	76.66	57.33	68.33	0.43^{v}	1.67^{v}
Plastic cont.	67.33	75.33	77.33	66.66	71.66	0.43^{c}	1.67^{c}
Steel cont.	74.66	82.66	84	77.33	79.66	$0.86^{v\times c}$	$3.35^{v\times c}$
Earthen pot	70.66	78.66	73.33	70.66	73.33		
Mean	69.33	77.83	77.83	68	73.25		
	Germination after 18 month						
Cotton bag	58.66	68.66	71.33	49.33	62	0.36^{v}	1.41^{v}
Plastic cont.	63.33	72.66	73.33	62	67.83	0.36^{c}	1.41c
Steel cont.	66.66	78	74.66	67.33	71.66	$0.73^{v\times c}$	$2.83^{v\times c}$
Earthen pot	68.66	74.66	70.66	54.33	67.08		
Mean	64.33	73.5	72.5	58.25	67.14		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

TABLE 5

Effect of packaging continuer on shoot length (cm) of wheat varieties

Container	Varieties: Shoot length after 6 month				Mean	SEm ±	CD (1%)
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	5.33	6.29	6.29	6.2	6.03	0.17^{v}	0.68^{v}
Plastic cont.	5.6	6.54	6.94	6.83	6.48	0.17^{c}	0.68^{c}
Steel cont.	5.19	6.63	10.54	6.42	7.19	$0.35^{v\times c}$	$1.37^{v\times c}$
Earthen pot	5.38	7.24	9.27	6.96	7.21		
Mean	5.37	6.67	8.26	6.6	6.73		

			Shoot length after 12 month				
Cotton bag	1.76	6.1	5.07	5.46	4.6	0.11^{v}	0.44^{v}
Plastic cont.	3.41	4.86	6.75	4.71	4.93	0.11^{c}	0.44c
Steel cont.	4.73	5.6	10.29	6.11	6.68	$0.23^{v \times c}$	$0.89^{v \times c}$
Earthen pot	5.23	6.96	8.85	6.41	6.86		
Mean	3.78	5.88	7.74	5.67	5.77		
			Shoot length after 18 month				
Cotton bag	0.2	3.96	4.9	3.76	3.2	0.97^{v}	0.37^{v}
Plastic cont.	0.1	4.7	3.86	4.4	3.26	0.97^{c}	0.37^{c}
Steel cont.	4.03	6.33	6.13	3.7	5.05	$0.19^{v \times c}$	$0.75^{v \times c}$
Earthen pot	4.23	4.73	5.16	3.9	4.5		
Mean	2.14	4.93	5.01	3.94	4		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

It's important to emphasize that the Critical Difference (CD) values provide a measure of the minimum difference required to establish statistical significance at the 1% level. The "v" and "c" annotations indicate significant differences between wheat varieties and container types, respectively. For instance, "0.17v" signifies a statistically significant difference between two wheat varieties, while "0.68c" indicates a significant difference between two container types.

The influence of different packaging containers on wheat root length at three different time points: 6, 12, and 18 months (Table 6). The table includes mean values, Standard Errors (SE), and Critical Difference (CD 1%) values, which are significant at a 1% confidence level. It is important to note that the critical difference values are specific to each container type and indicate the minimum difference required to establish statistical significance at the 1% level. For instance, if the difference between two means is greater than the critical difference for a particular container type, it is considered statistically significant at the 1% level.

The data suggests that steel containers had the highest mean root length at 6 and 12 months, while plastic containers exhibited the highest mean root length at 18 months. This underscores the substantial impact of container choice on wheat root length, with the choice of wheat variety also playing a role. Seedling root length was consistently highest in tin containers [20]. Furthermore, in most instances, the height of coriander seedlings was greater when grown in tin containers compared to polyethylene and jute bags [19].

The results of an experiment investigating the influence of various packaging containers on the fresh weight of wheat seedlings after 6, 12, and 18 months (Table 7). The data is categorized by container type, including Cotton bags, Plastic containers, Steel containers and earthen pots, as well as by wheat variety, such as VL-802, VL-829, VL-892, and UP-1109. The table also provides the mean values and standard errors for each combination.

The findings reveal that after 6 months, the Steel container exhibited the highest average seedling fresh weight, followed by the plastic container, cotton bag, and earthen pot. Similarly, after 12 months, the steel container had the highest mean fresh weight with the plastic container, cotton bag, and earthen pot following in that order. After 18 months, the steel container continued to lead with the highest mean fresh weight, followed by the Earthen pot, Plastic container, and Cotton bag. Lower germination percentages in chickpeas when using cloth bags [21]. Additionally, wheat varieties demonstrated variations in seedling fresh weight, as noted [14].

In summary, the choice of container significantly influences the fresh weight of wheat seedlings over time, and the impact can vary depending on the wheat variety. Steel containers consistently outperform other containers in terms of mean seedling fresh weight, while cotton bags and plastic containers tend to yield similar results.

The impact of various packaging containers on the dry weight of wheat seedlings after 6, 12 and 18 months shown in Table 8. The data is organized by the type of container and the variety of wheat, with means and standard errors included. Critical Differences (CD) at a significance level of 1% are provided to highlight statistically significant differences between the means. The choice of packaging container appears to influence the dry weight of wheat seedlings over time, and the specific wheat variety may also affect the results. The critical differences indicate where significant disparities exist between the mean values. The highest dry weight of seedlings was observed in steel containers, while the lowest was recorded in cotton bags. Moisture absorption in earthen pots leads to seed deterioration [16]. This process is gradual and accompanied by the accumulation of metabolites, resulting in a decline in germination and seedling growth as seeds age, ultimately reducing seedling dry weight during storage. Variations in seedling dry weight were also influenced by the interaction between different storage containers and wheat varieties across different storage periods. The greatest dry weight of seedlings was found in the VL-892 variety, while the least was observed in the VL-829 variety. Wheat varieties themselves exhibited differences in terms of seedling dry weight [14]. In addition, the interaction effect of different storage containers and varieties at various storage periods played a significant role in determining seedling dry weight. Specifically, the maximum seedling dry weight was associated with the steel container and VL-892 variety combination, while the minimum was linked to the cotton bag and VL-829 treatment combination.

TABLE 6

Effect of packaging container on the root length (cm) of wheat varieties

Container	Variety				Mean	SE ±	CD (1%)
	Root length after 6 month						
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	6.32	11.6	10.91	11.8	10.16	0.15^{v}	0.61^{v}
Plastic cont.	11.11	11.38	11.24	12.56	11.57	0.15^{c}	0.61^{c}
Steel cont.	12.44	11.36	13.95	13.54	12.82	$0.31^{v \times c}$	$1.22^{v \times c}$
Earthen pot	10.32	10.96	13.95	11.84	11.37		
Mean	10.05	11.32	12.11	12.44	11.48		
			Root length after 12 month				
Cotton bag	3.52	10.23	9.8	10.43	8.49	0.12^{v}	0.46^{v}
Plastic cont.	7.43	10.72	10.7	11.44	10.07	0.12^{c}	0.46^{c}
Steel cont.	11.46	10.59	12.6	11.23	11.47	$0.24^{v \times c}$	$0.93^{v \times c}$

Earthen pot	9.5	10.42	10.26	10.3	10.12		
Mean	7.98	10.49	10.84	10.85	10.04		
			Root length after 18 month`				
Cotton bag	0.1	8.4	7.44	9.49	6.36	0.84^{v}	0.32^{v}
Plastic cont.	0.1	10.36	8.86	9.73	7.26	0.84^{c}	0.32^{c}
Steel cont.	10.86	9.4	12.4	9.3	10.49	$0.16^{v\times c}$	$0.65^{v\times c}$
Earthen pot	8.42	9.4	9.56	9.53	9.23		
Mean	4.87	9.39	9.57	9.51	8.33		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

TABLE 7
Effect of packaging container on fresh weight (gm) of wheat varieties

Container	Variety				Mean	SE ±	CD (1%)
	Fresh weight after 6 month						
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	0.53	0.56	0.66	0.64	0.6	0.12^{v}	0.49^{v}
Plastic cont.	0.63	0.54	0.71	0.64	0.63	0.12^{c}	0.49^{c}
Steel cont.	0.85	0.65	1.66	0.82	0.99	$0.25^{v\times c}$	$0.99^{v\times c}$
Earthen pot	0.66	0.75	0.73	0.7	0.71		
Mean	0.67	0.62	0.94	0.7	0.73		
			Fresh weight after 12 month				
Cotton bag	0.42	0.53	0.43	0.54	0.48	0.18^{v}	0.71^{v}
Plastic cont.	0.45	0.46	0.58	0.57	0.51	0.18^{c}	0.71^{c}
Steel cont.	0.73	0.41	0.83	0.74	0.68	$0.36^{v\times c}$	$0.14^{v\times c}$
Earthen pot	0.64	0.65	0.72	0.51	0.63		
Mean	0.56	0.51	0.64	0.59	0.57		
			Fresh weight after 18 month				
Cotton bag	0.27	0.37	0.35	0.48	0.36	0.20^{v}	0.77^{v}
Plastic cont.	0.31	0.43	0.35	0.34	0.36	0.20^{c}	0.77^{c}
Steel cont.	0.51	0.34	0.62	0.41	0.47	$0.40^{v\times c}$	$0.15^{v\times c}$
Earthen pot	0.5	0.53	0.54	0.32	0.47		
Mean	0.4	0.42	0.46	0.39	0.42		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

TABLE 8
Effect of packaging container on dry weight (gm) of wheat varieties

Container	Variety				Mean	SE ±	CD (1%)
	Dry weight after 6 month						
	VL-802	VL-829	VL-892	UP-1109			
Cotton bag	0.13	0.46	0.6	0.6	0.74	0.11^{v}	0.44^{v}
Plastic cont.	0.43	0.53	0.66	0.6	0.55	0.11^{c}	0.44^{c}
Steel cont.	0.53	0.56	0.5	0.6	0.55	$0.26^{v\times c}$	$0.88^{v\times c}$
Earthen pot	0.6	0.63	0.6	0.6	0.55		
Mean	0.71	0.55	0.59	0.6	0.61		
			Dry weight after 12 month				
Cotton bag	0.26	0.56	0.29	0.6	0.1	0.29^{v}	0.11^{v}
Plastic cont.	0.46	0.53	0.53	0.6	0.53	0.29^{c}	0.11^{c}
Steel cont.	0.7	0.53	0.65	0.6	0.62	$0.58^{v\times c}$	$0.22^{v\times c}$
Earthen pot	0.46	0.65	0.6	0.6	0.58		
Mean	0.47	0.57	0.11	0.6	0.7		
			Dry weight after 18 month				
Cotton bag	0.1	0.53	0.6	0.6	0.45	0.13v	0.51v
Plastic cont.	0.1	0.6	0.6	0.6	0.47	0.13c	0.51c
Steel cont.	0.32	0.63	0.6	0.6	0.54	0.26v×c	0.10v×c
Earthen pot	0.46	0.56	0.6	0.6	0.55		
Mean	0.96	0.58	0.6	0.6	0.68		

Note: ^{v}=Variety, ^{c}=Container, ^{vxc}=Variety × Container.

CONCLUSION

This comparative study on the impact of different packaging materials on seed quality parameters of four wheat varieties during storage periods has provided valuable insights into the preservation of seed quality in wheat. The results clearly demonstrate the critical role that packaging materials and storage duration play in maintaining seed quality. Steel containers consistently emerged as the top choice for preserving seed quality, exhibiting the highest 1000 seed weight and superior maintenance of seed vigor and germination rates. Steel containers were found to be the best choice, while cotton bags performed the least favorably. Seed moisture content decreased with longer storage, and the wheat variety VL-892 showed promise for prolonged storage. In contrast, cotton bags, although cost-effective, exhibited the least favorable performance across all parameters, including seed moisture content and seedling characteristics. Moisture content, a crucial factor in seed longevity, decreased with longer storage periods, reinforcing the importance of managing seed moisture during storage. The findings also underline the decline in seed vigor and germination rates with extended storage periods, highlighting the need for regular assessment and monitoring of seed quality. Shoot and root lengths, as well as seedling fresh and dry weights, were influenced by both the choice of storage container and the wheat variety, further emphasizing the complexity of managing seed quality. The study underscores the need for regular seed quality assessment and highlights the complexity of managing seed quality. Ultimately, these findings should inform agricultural practices and seed storage management to enhance crop yield and genetic integrity for food security and sustainable agriculture.

REFERENCES

1. Jing RL, Chang XP. Genetic diversity in wheat (*T. aestivum*) germplasm resources with drought resistance. Acta Bot Boreal-Occid Sin. 2003;23(3):410.
2. Ahmad T, Pathak SK, Gupta JP, et al. Effect of storage containers to stabilize the seed Quality in wheat (*Triticum aestivum* L.). Int J Environ Clim Chang. 2022; 12(11):2729-2735.
3. Bhuker A, Kurubar SA, Kumar Y. Effect of priming and storage containers on seed quality of barley (*Hordeum vulgare* L.). J Cereal Res. 2021;13(S1).
4. El-Seidy ES, Rashwan EE, Selim A, et al. Effect of packages types and some treatments on wheat seed during storage. EUREKA: Life Sciences. 2022;(6):13-24.
5. Marcos Filho J. Physiology of seeds of cultivated plants. Fealq, Brasil. 2005.
6. Melese B, Satheesh N, Fanta SW, et al. Effects of storage bags type and storage duration on seed quality and proximate composition of emmer wheat (*Triticum dicoccum* L.) in Ethiopia. Heliyon. 2022;8(12).
7. Rahouma A, Mahmud A. Effect of storage periods and package types on germination, seedling characters and biochemical changes of barley grains. Alex Sci Exch J. 2021;42: 133-138.
8. Sayed TS, Hirad FY, Abro GH. Resistance of different stored wheat varieties to Khapra beetle, *Trogoderma granarium* (Everest) and lesser grain borer, *Rhizopertha dominica* (Fabricus). Pak J Biol Sci. 2006;9(8):1567-1571.
9. Sinha MK, Sharma PD. Storage performance of wheat in different storage structures. J Appl Biol. 2004; 14:83-85.
10. Kamruzzaman M, Khatun S, Rakib A, et al. Temporal variation in seed quality of Indian spinach preserved in different containers. Int J Agric Res Innov Technol. 2015;5: 51-57.
11. Khatri N, Pokhrel D, Pandey BP, et al. Effect of different storage materials on the seed temperature, seed moisture content and germination of wheat under farmer's field condition of Kailali district, Nepal. Sci Technol. 2019; 11:352-355.
12. Uddin MJ. Effect of storage environment on seed longevity. Hand note, Certificate course of seed technology, Sher-e-Bangla Agricultural University, Dhaka, Bangldesh. 2005.
13. Quais MK, Jahan S, Haque MM, et al. Variation in seed quality of radish preserved in different storage containers. Bangladesh J Agric Res. 2013; 38(3):545-552.
14. Naguib NA, Mohamed EA, EL-AIDY NA. Effect of storage period and packaging material on wheat (*Triticum aestivum* L.) seed viability and quality. Egypt J Agric Res. 2011; 89(4):1481-1497.
15. Yaja J, Pawelzik E, Vearasilp S. Prediction of soybean seed quality in relation to seed moisture content and storage temperature. In Conference on International Agricultural Research for Development. 2005.
16. Akter N, Haque MM, Islam MR, et al. Seed quality of stored soybean (*Glycine max* L.) as influenced by storage containers and storage periods. The Agriculturists. 2014; 12(1):85-95.
17. Seadh SE, Badawi MA, Abdel-Moneamand MA, et al. Germination and seedling parameters of wheat as affected by storage conditions. In IOP Conference Series: Earth Environ Sci. 2021; 012035.
18. Anonymous. Quality declared seed: technical guidelines for standards and procedures, FAO Plant Production and Protection Paper 185 Rome, Italy. 2006.
19. Rahman MS, Hossain I, Mansur MA, et al. Effect of storage condition on the quality of wheat seed. Bangladesh J Agril Sci. 1985;12(1):49-54.
20. Nabila SM, Amin AK, Islam MO, et al. Effect of storage containers on the quality of wheat seed at ambient storage condition. Am-Eurasian J Agric Environ Sci. 2016;16(2):402-409.
21. Vidyashree AS. Biology and Management of Pulse Beetle *Callosobruchus Maculatus* Fab. on Chikpea and Screening of Chickpea Entries for Resistance (Doctoral dissertation, University of Agricultural Sciences, GKVK).