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RESEARCH ARTICLE

Influence of different packaging materials on storability of different French bean (*Phaseolus vulgaris* L.) genotypes

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Abstract

Storage is an important part of any seed programme, as it helps in maintaining seed quality from harvest until sowing. The present investigation was conducted to evaluate the storability of eight French bean genotypes collected from different regions of Uttarakhand [White Rajma (V1), Harshil Rajma (V2), Munsyari Rajma (V3), Chitkabri Rajma (V4), Red Rajma (V5), Tehri Rajma (V6), Chakrata Rajma (V7) and Chitra Rajma (V8)]. The seeds were stored for 120 days in three different packaging materials, namely, polythene bags, steel containers and cloth bags under ambient conditions. The findings demonstrated significant variations among genotypes, packaging materials and their interactions during the storage duration. Among all the genotypes, Harshil Rajma (V2) maintained seed quality and viability better than the other genotypes during storage. It was recorded that the steel containers provided better storage conditions than cloth bags and polyethylene bags, with the highest mean germination (92.15 %), lowest moisture content range (8.6–9.2 %), higher fresh and dry seedling weight and vigour index-I (2019.49). In contrast, seeds stored in cloth bags showed the fastest deterioration during storage. Genotype Harshil Rajma (V2) stored in steel containers recorded the highest vigour index-I (2019.49) after 30 days of storage, indicating better storability for French beans.

Keywords: deterioration; genotypes; packaging material; storability

Introduction

Seed storage is an important process that helps in maintaining seed quality, vigour and integrity of seeds from harvest until the next planting season. French bean is an important legume crop and is often referred to as “poor man’s meat” because of its high protein content (1). But a major constraint is seed deterioration during storage. The principal goal of seed storage is to ensure a continuous supply of good quality planting material (2, 3). However, maintaining seed quality is a foremost challenge after harvesting, as several physical factors affect the storage life of seeds. The three main factors that influence seed quality during storage are moisture content, temperature and type of packaging material used. Selecting the right packaging material is important for storing seeds for a longer period. Previous studies have shown that the packaging material has a significant effects on seed quality parameters such as germination percentage and vigour (4–6). French bean seeds generally have relatively high moisture content, which accelerates deterioration as the moisture content increases (7, 8). Therefore, moisture-impervious containers are preferred for long-term storage, even under hot and humid conditions, provided that the seeds are stored at the optimum moisture content. The present study was conducted to assess the effect of different packaging materials on the storage life and seed quality of French bean (*Phaseolus vulgaris* L.) seeds and to identify the most suitable packaging material for their long-term storage, since seed quality in this crop is also strongly influenced by pre-storage treatments and genotype (9).

Materials and Methods

In the present study, eight genotypes of French bean were collected from different regions of Uttarakhand, namely White Rajma (V1), Harshil Rajma (V2), Munsyari Rajma (V3), Chitkabri Rajma (V4), Red Rajma (V5), Tehri Rajma (V6), Chakrata Rajma (V7) and Chitra Rajma (V8). Three types of packaging materials were used for seed storage: polythene bags, steel containers and cloth bags. Seed quality was evaluated at the end of each storage period. All seeds were stored under ambient conditions at room temperature (25 ± 2 °C) for 30, 60, 90 and 120 days. Seed quality was evaluated at the end of each storage period. after. Seed moisture content was measured using the oven-dry method (103 ± 2 °C for 17 hr) following ISTA rules. The experiment was laid out using completely randomised design (CRD). Twenty-five seeds from each treatment were placed on moist paper towels and incubated in a germinator at 25 °C. Observation on germination percentage, moisture content, root length, shoot length, seedling length, fresh weight, dry weight, vigour index-I, vigour index-II and weight loss were recorded. The data were analysed using SPSS software.

Results and Discussion

Effect of packaging materials on French bean genotypes after 30 days of storage

The effects of different packaging materials on the seed quality of French bean genotype after 30 days of storage are presented in Table 1. The highest germination percentage (81.34 %) was recorded in genotype V2 stored in a steel container, while the lowest germination percentage (70.36 %) was observed in genotype V1 stored in a polythene bag. The moisture content ranged from (8.4–9.0 %) after 30 days of storage. Higher moisture content was observed in genotype V4 and V7 stored in cloth bags, while the lowest moisture content V1(8.4 %) was recorded in genotype V1 stored in a steel containers. Root length varied from 5.20 cm (V1, cloth bag) to 8.25 cm for V2 in a steel container. Shoot length ranged from 10.20 cm (V1, cloth bag) to 13.4 cm for V2 (steel container). Fresh weight was lowest for V8 in a cloth bag (0.32 g) and highest for V3 in a steel container (4.15 g). Among the genotypes, V2 showed the highest dry weight across all packaging materials. Vigour index-I ranged from 1242.63 in genotype V1 stored in a cloth bag to 1958.24 in genotype V7 stored in a steel container. Genotype V2 stored in a steel container was highest vigour index-II (256.90), whereas the lowest value (7.67) VI-II was found in genotype V8 stored in a polythene bag. The percentage weight loss ranged from 16.47 % (V1, cloth bag) to 30.64 % (V2, steel container) among the different treatments.

Effect of packaging materials on French bean genotypes after 60 days of storage

The influence of packaging materials on seed quality of eight Rajma genotypes (V1–V8) after 60 days of storage is presented in Table 2. Among the genotypes, V2 showed the highest germination (91.24 %) in steel containers, while V1 had the lowest (78.26 %) in polythene bags. Moisture content ranged from 7–9.5 %. Seeds stored in a cloth bags showed higher moisture content due to their porous nature. The maximum root length (10.75 cm) was recorded in V2 stored in steel containers, while V1 stored in a cloth bag had the shortest (4.9 cm) roots. For shoot length, V2 in steel containers was the highest (15.85 cm) and V1 the lowest (9.8 cm) in cloth bags. Fresh weight was highest (5.65 g) in genotype V2 stored in a steel storage and lowest (0.29 g) in genotype V8 stored in cloth bag. Dry weight ranged from 0.08–2.75 g, with the highest value recorded in genotype V2 and V8 stored in steel containers showing, which may be attributed to the favourable storage conditions provided by the steel container. The highest vigour index-I (1860.44) was recorded in V stored in steel container, followed by V2 (1844.73) under the same storage condition. The lowest value (1173.90) was recorded in V1 stored in polyethylene bag. These results indicate that steel containers were more effective in maintaining seed vigour during storage. The highest vigour index-II (246.26) was recorded in genotype V2 stored in a steel container, followed by V2 stored in a polythene bag (228.25). The lowest value (6.73) was observed in genotype V8 stored in a cloth bag, indicating that seed vigour was better maintained in steel container than in cloth bag. The minimum weight loss (13.48 %) was recorded in genotype V2 stored in a steel container, whereas the maximum weight loss (30.72 %) was observed in V7 stored in a polyethylene bags container, indicating variation in seed performance under different storage environments. Similar trends of

Table 1. Effect of packaging material on different French bean genotypes after 30 days of storage

Packaging material	Genotypes	Germination (%)	Moisture content (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight (g)	Dry weight (g)	VI-I	VI-II	Weight loss (%)
Polyethylene bag	V1	70.36	6.9	5.25	10.35	15.60	3.50	2.50	1253.62	200.90	28.12
	V2	85.12	7.7	7.80	12.95	20.75	3.65	2.73	1869.99	246.03	19.74
	V3	81.38	7.1	7.60	12.80	20.40	4.00	2.00	1823.35	178.76	26.15
	V4	73.74	6.8	6.45	11.65	18.10	4.10	1.90	1533.79	161.01	23.12
	V5	79.77	7.2	6.00	11.15	17.15	3.95	2.15	1453.81	182.26	28.89
	V6	76.42	6.6	6.75	11.95	18.70	3.75	2.70	1597.35	230.63	24.34
	V7	74.47	7.5	8.15	13.30	21.45	3.80	2.20	1919.13	196.83	23.88
	V8	72.24	6.9	6.95	12.15	19.10	0.33	0.09	1628.08	7.67	22.27
Steel container	V1	81.34	8.4	5.35	10.50	15.85	3.58	2.58	1289.24	209.86	20.24
	V2	91.47	8.6	8.25	13.40	21.00	3.73	2.82	1913.10	256.90	15.28
	V3	90.36	8.5	7.70	12.90	20.60	4.15	2.07	1861.42	187.05	23.41
	V4	85.72	8.7	6.55	11.75	18.30	4.23	1.95	1568.68	167.15	20.89
	V5	85.75	8.5	6.05	11.25	17.30	4.05	2.22	1483.48	190.37	19.32
	V6	86.40	8.6	6.85	12.05	18.90	3.85	2.80	1632.96	241.92	22.06
	V7	90.45	8.8	7.90	13.10	21.65	3.92	2.30	1958.24	208.04	21.31
	V8	86.22	8.6	7.05	12.25	19.30	0.34	0.095	1664.05	8.19	20.11
Cloth bag	V1	80.69	8.6	5.20	10.20	15.40	3.40	2.45	1242.63	197.69	22.47
	V2	91.10	8.9	7.70	12.80	20.50	3.55	2.68	1875.14	245.14	18.37
	V3	90.47	8.8	7.55	12.65	20.20	3.95	2.00	1827.49	180.94	23.68
	V4	89.63	9.0	6.40	11.55	17.95	4.05	1.85	1608.86	165.82	25.50
	V5	85.47	8.7	5.95	11.05	17.00	3.85	2.10	1452.99	179.49	28.47
	V6	85.17	8.8	6.70	11.85	18.55	3.70	2.65	1579.90	225.70	24.17
	V7	90.12	9.0	8.10	13.20	21.30	3.75	2.20	1919.56	198.26	25.11
	V8	85.47	8.7	6.90	12.05	18.95	0.32	0.09	1619.66	7.69	21.72
CD (α = 0.05)											
Genotypes	3.44	0.32	0.31	0.41	0.62	0.26	0.14	55.34	11.41	0.98	
Packaging material	2.10	0.20	0.19	0.25	0.38	0.16	0.09	33.89	6.99	0.60	
Genotype × Packaging material	5.95	0.56	0.54	0.70	1.08	0.44	0.24	95.85	19.76	1.70	

VI-I: vigour index-I; VI-II: vigour index-II. V1: White Rajma; V2: Harshil Rajma; V3: Munsyari Rajma; V4: Chitkabri Rajma; V5: Red Rajma; V6: Tehri Rajma; V7: Chakrata Rajma; V8: Chitra Rajma.

Table 2. Effect of packaging materials on French bean genotypes after 60 days of storage

Packaging material	Genotypes	Germination (%)	Moisture content (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight (g)	Dry weight (g)	VI-I	VI-II	Weight loss (%)
Polyethylene bag	V1	78.26	8.0	5.00	10.00	15	3.30	2.35	1173.90	183.91	21.58
	V2	88.47	8.2	7.50	12.55	20.05	3.45	2.58	1773.82	228.25	20.05
	V3	88.15	8.4	7.30	12.42	19.72	3.80	1.88	1736.56	165.72	28.99
	V4	83.47	7.0	6.20	11.35	17.55	3.90	1.78	1464.90	148.58	23.96
	V5	80.26	8.7	5.75	10.85	16.6	3.75	2.03	1332.32	162.93	24.73
	V6	83.14	8.8	6.45	11.60	18.05	3.55	2.55	1500.68	212.01	24.18
	V7	86.47	8.3	7.85	12.90	20.75	3.60	2.08	1794.25	179.86	30.72
	V8	84.36	8.8	6.65	11.80	18.45	0.31	0.08	1556.44	6.75	25.11
Steel container	V1	80.11	8.5	5.20	10.25	15.45	3.50	2.50	1225.80	198.35	19.08
	V2	91.24	9.5	10.75	15.85	26.6	5.65	2.75	1844.73	246.26	13.48
	V3	89.69	8.6	7.55	12.65	20.2	4.05	2.00	1802.45	178.46	20.25
	V4	89.11	8.8	6.40	11.55	17.95	4.15	1.90	1517.67	160.65	26.73
	V5	84.20	8.6	5.90	11.05	16.95	3.95	2.15	1378.71	174.88	27.16
	V6	83.69	8.7	6.70	11.85	18.55	3.75	2.70	1562.28	227.39	26.90
	V7	88.21	8.9	8.10	13.15	21.25	3.82	2.22	1860.44	194.36	25.15
	V8	84.17	8.7	6.90	12.05	18.95	0.33	0.09	1619.09	7.69	24.95
Cloth bag	V1	79.34	8.1	4.90	9.80	14.7	3.15	2.25	1177.62	180.25	22.46
	V2	89.55	8.9	7.30	12.30	19.6	3.30	2.45	1788.30	223.54	19.86
	V3	89.23	7.0	7.15	12.20	19.35	3.70	1.85	1735.50	165.93	28.63
	V4	84.55	8.4	6.05	11.10	17.15	3.80	1.70	1528.24	151.49	23.11
	V5	81.34	7.9	5.60	10.65	16.25	3.60	1.95	1368.25	164.19	23.54
	V6	84.22	8.1	6.35	11.40	17.75	3.45	2.45	1485.50	205.04	23.28
	V7	87.55	8.3	7.70	12.75	20.45	3.50	2.00	1803.89	176.42	29.53
	V8	85.44	7.9	6.55	11.60	18.15	0.29	0.08	1527.69	6.73	26.33
CD (α=0.05)											
Genotypes	2.76	0.31	0.36	0.41	0.64	0.30	0.16	54.78	11.62	1.01	
Packaging materials	1.59	0.18	0.21	0.24	0.37	0.17	0.09	31.62	6.71	0.58	
Genotypes × Packaging materials	4.78	0.54	0.62	0.71	1.11	0.52	0.27	94.86	20.12	1.75	

VI-I: vigour index-I; VI-II: vigour index-II. V1: White Rajma; V2: Harshil Rajma; V3: Munsyari Rajma; V4: Chitkabri Rajma; V5: Red Rajma; V6: Tehri Rajma; V7: Chakrata Rajma; V8: Chitra Rajma.

reduced deterioration in moisture-impervious packaging have also been reported in other legumes such as lentil (10).

Effect of packaging materials on French bean genotypes after 90 days of storage

The effects of different packaging materials on the seed quality of eight Rajma genotypes after 90 days of storage are presented in Table 3. Genotype V2 stored in a steel container recorded the highest germination (89.44 %), whereas genotype V1 stored in polyethylene and cloth bags recorded the lowest germination (75.87 %). Moisture content ranged from 7.0–11.8 %, with steel containers showing higher moisture higher moisture content than the other packaging materials due to their permeable nature. Root length was longest in genotype V2 (7.55 cm) stored in a steel container and shortest in genotype V1 (4.55 cm) stored in cloth, indicating poor seedling vigour under high humidity. Shoot length also peaked in genotype V2 (12.60 cm) and V7 (12.45 cm) in steel, with V1 at 9.3 cm in cloth bags. The highest fresh weight (5.55 g) was recorded in a steel container, while the lowest fresh weight (0.26 g) was observed in genotype V8 stored in a cloth bag, highlighting the benefits of superior storage conditions. The dry weight of seedlings ranged from 0.07–2.65 g. The highest dry weight was recorded in genotype V2 (2.65 g), followed by V6 (2.60 g), both stored in steel containers. The lowest dry weight (0.07 g) was observed in genotype V8, indicating better seedling growth under steel storage conditions. Vigour index-I showed a maximum of 1785.61 in genotype V2 (steel container) and a minimum of 1081.15 in genotype V1 (cloth bag), showing the positive effect of steel containers on seed quality. Vigour index-II ranged from 5.47–226.41, with the highest value recorded in genotype V2 stored in a steel container and the lowest in genotype V8 stored in a cloth bag. This indicates that seed vigour was better maintained in steel container. Weight loss was lowest at 16.85 % in V2 (steel container) and highest at 34.50 % in V7 (polyethylene bag), a pattern consistent with findings in chickpea, where packaging material strongly influenced storage life (11).

Effect of packaging materials on French bean genotypes after 120 days of storage

The effect of storage, significant variation in seed quality were observed among the packaging materials after 120 days are depicted in Table 4. The highest germination percentage (88.64 %) was recorded in seeds stored in steel container, followed by genotype V2 (88.64 %), while the lowest (70.25 %) in polythene bags, indicating seed viability in a steel containers. Moisture content was lowest in seeds stored steel container (7.4–9.6 %) and highest in cloth bags (8.8 –12.2 %). These findings agree with the previous reports on seed storage in eggplant (6) and the effects of storage duration on seed deterioration in rice (12). Fresh and dry seedling weights were also highest in steel containers recording 2.50 g and 1.87 g respectively. In contrast, the lowest value was observed in cloth bags, with fresh and dry weight of 0.06 g and 0.01 g, respectively. The highest vigour index-I (2783.03) was recorded in genotype V2 stored in a steel container, while the lowest value (1524.14) observed in genotype V1 stored in a cloth bag, mirroring earlier reports of genotype-dependent packaging responses in Indian bean (13) and storage-duration-related viability decline in corn (14). Similarly, the highest vigour index-II (27.58) was recorded in genotype V2 stored in a steel containers, whereas the lowest value (0.27) was found in genotype V8 stored in a cloth bags.

Table 3. Effect of packaging materials on French bean genotypes after 90 days of storage

Packaging material	Genotypes	Germination (%)	Moisture content (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight (g)	Dry weight (g)	VI-I	VI-II	Weight loss (%)
Polyethylene bag	V1	75.87	8.0	4.70	9.55	14.25	3.10	2.20	1081.15	166.91	23.40
	V2	83.25	8.2	7.15	12.10	19.25	3.20	2.43	1602.56	202.30	19.08
	V3	85.69	8.1	6.95	12.00	18.95	3.55	1.75	1623.83	149.96	32.20
	V4	80.47	7.3	5.90	11.00	16.9	3.65	1.65	1359.94	132.78	26.00
	V5	77.41	7.0	5.45	10.45	15.9	3.50	1.90	1230.82	147.08	27.30
	V6	82.47	8.1	6.15	11.20	17.35	3.35	2.40	1430.85	197.93	26.70
	V7	81.28	7.2	7.50	12.45	19.95	3.40	1.95	1621.54	158.50	34.50
	V8	78.14	8.1	6.35	11.40	17.75	1.29	0.08	1386.99	6.25	27.90
Steel container	V1	78.06	8.6	5.05	10.00	15.05	3.40	2.40	1174.80	187.34	21.00
	V2	89.44	11.8	7.55	12.60	20.15	5.55	2.65	1785.61	226.41	16.85
	V3	85.88	9.2	7.35	12.40	19.75	3.95	1.92	1735.62	168.73	29.30
	V4	82.66	8.9	6.25	11.30	17.55	4.05	1.82	1450.67	150.44	23.00
	V5	79.60	8.7	5.75	10.80	16.55	3.85	2.05	1317.37	163.18	24.10
	V6	84.66	9.8	6.50	11.60	18.1	3.65	2.60	1532.34	220.11	25.00
	V7	83.47	9.0	7.90	12.90	20.8	3.72	2.13	1736.17	177.79	31.00
	V8	80.33	8.8	6.70	11.80	18.5	0.32	0.085	1486.10	6.83	27.00
Cloth bag	V1	75.87	8.6	4.55	9.30	13.85	2.85	2.05	1050.80	155.53	21.00
	V2	83.25	8.1	6.85	11.70	18.55	3.00	2.25	1544.29	187.31	18.52
	V3	85.69	8.8	6.70	11.65	18.35	3.40	1.70	1572.41	145.67	29.30
	V4	80.47	8.3	5.70	10.60	16.3	3.50	1.55	1311.66	124.73	23.00
	V5	77.41	7.7	5.25	10.15	15.4	3.30	1.75	1192.11	135.47	24.10
	V6	82.47	8.0	6.00	10.90	16.9	3.15	2.25	1393.74	185.56	25.00
	V7	81.28	8.2	7.25	12.20	19.45	3.20	1.85	1580.90	150.37	31.00
	V8	78.14	8.7	6.15	11.10	17.25	0.26	0.07	1347.92	5.47	27.00
CD (α = 0.05)											
Genotypes	3.44	0.32	0.35	0.44	0.79	0.33	0.16	68.65	12.23	1.15	
Packaging materials	2.46	0.23	0.25	0.31	0.56	0.24	0.11	49.03	8.73	0.82	
Genotypes × Packaging materials	6.03	0.55	0.61	0.77	1.38	0.59	0.28	120.13	21.40	2.01	

VI-I: vigour index-I; VI-II: vigour index-II. V1: White Rajma; V2: Harshil Rajma; V3: Munsyari Rajma; V4: Chitkabri Rajma; V5: Red Rajma; V6: Tehri Rajma; V7: Chakrata Rajma; V8: Chitra Rajma.

Table 4. Effect of packaging materials on French bean genotypes after 120 days of storage

Packaging material	Genotypes	Germination (%)	Moisture content (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight (g)	Dry weight (g)	VI-I	VI-II	Weight loss (%)
Polyethylene bag	V1	70.25	8.4	9.00	13.40	22.40	2.00	0.88	1573.60	19.71	26.35
	V2	81.47	9.6	11.50	18.20	29.70	2.25	0.03	2419.66	22.56	21.85
	V3	84.36	8.5	11.40	17.95	29.35	1.60	0.48	2475.97	14.09	32.20
	V4	77.47	7.7	10.50	16.00	26.50	1.50	0.38	2052.96	10.07	28.55
	V5	70.28	7.3	9.95	15.05	25.00	1.75	0.63	1757.00	15.75	26.40
	V6	78.36	7.4	10.70	16.50	27.20	2.20	1.08	2131.39	21.38	29.85
	V7	80.41	8.6	11.90	19.00	30.90	1.80	0.68	2484.67	21.01	30.85
	V8	73.47	8.4	10.90	16.90	27.80	0.07	0.03	2042.47	0.83	26.95
Steel container	V1	73.42	7.4	9.70	14.55	24.25	2.25	1.08	1780.39	22.19	28.55
	V2	88.64	8.9	12.55	20.20	32.75	2.50	1.87	2783.03	27.58	18.90
	V3	85.24	9.6	12.00	19.10	31.10	1.80	0.66	2650.96	20.53	33.15
	V4	80.64	8.0	11.00	17.00	28.00	1.70	0.47	2257.86	13.16	30.85
	V5	73.45	8.5	10.50	16.00	26.50	1.90	0.69	1946.37	18.29	28.60
	V6	81.53	9.8	11.30	17.55	28.85	2.45	1.07	2352.08	30.87	31.65
	V7	83.58	9.1	12.20	19.50	31.70	2.00	1.67	2637.18	21.94	32.85
	V8	76.64	9.4	11.50	17.95	29.45	0.08	1.01	2256.99	0.29	30.45
Cloth bag	V1	70.89	8.8	8.70	12.80	21.50	1.80	0.41	1524.14	8.82	28.65
	V2	78.27	12.2	11.00	17.30	28.30	2.00	0.58	2215.04	16.41	20.60
	V3	80.71	9.0	11.00	17.20	28.20	1.50	0.63	2276.02	17.77	32.40
	V4	75.49	9.1	10.00	15.30	25.30	1.35	0.78	1909.90	19.73	29.55
	V5	72.43	8.9	9.60	14.40	24.00	1.55	0.88	1738.32	21.12	28.30
	V6	77.49	9.0	10.30	15.85	26.15	2.00	0.47	2026.36	12.29	30.30
	V7	76.30	10.2	11.50	18.20	29.70	1.60	0.25	2266.11	7.43	29.85
	V8	73.16	9.0	10.50	16.20	26.70	0.06	0.01	1953.37	0.27	28.95
CD (α = 0.05)											
Genotypes	3.42	0.32	0.31	0.42	0.82	0.35	0.13	65.33	11.08	3.22	
Packaging materials	2.44	0.23	0.22	0.30	0.59	0.25	0.10	46.66	7.92	2.30	
Genotypes × Packaging materials	5.99	0.57	0.54	0.73	1.44	0.61	0.23	114.32	19.40	5.64	

VI-I: vigour index-I; VI-II: vigour index-II. V1: White Rajma; V2: Harshil Rajma; V3: Munsyari Rajma; V4: Chitkabri Rajma; V5: Red Rajma; V6: Tehri Rajma; V7: Chakrata Rajma; V8: Chitra Rajma.

Conclusion

This study concluded that French bean seeds of genotype V2 (Harshil Rajma) stored in steel containers maintained the highest seed quality parameters during 120 days of storage compared to the other treatments. Steel containers can also be used for transporting seeds to markets, as they help protect the seeds from physical damage. Under ambient conditions, polythene bags and cloth bags are suitable only for short-term storage. Cloth bags were unsuitable for long-term storage, as seeds stored in them showed the highest rate of deterioration during the storage period. The rate of deterioration was highest in cloth bags.

Future research should investigate: (i) genotype × packaging interactions under controlled temperature and humidity conditions; (ii) the seed coat biochemistry of high-performing genotypes; (iii) the feasibility of steel container storage at the farm level; (iv) the effects of desiccants or modified-atmosphere packaging; and (v) storage periods beyond 120 days to determine the maximum seed longevity.

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Authors' contributions

AT carried out the data Collection and manuscript writing. GC (corresponding author) drafted the manuscript. PB participated in manuscript writing. AD and HP performed the statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Author do not have any conflict of interest to declare

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