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Seed quality of stored soybean *(Glycine max) seeds as* influenced by packaging materials and storage conditions

Meena, M. K.*, M.M.Dhanoji, M. Chandra Naik, Amaregouda, Vijaykumar K and Afshana Manik

Department of Crop Physiology, UAS, Raichur-584104 Karnataka India.

ABSTRACT

A lab experiment was carried out to study the Seed quality of stored soybean (Glycine max) seeds as influenced by packaging materials and storage conditions. Soybean seeds (JS-335) were stored in different packaging materials viz., gunny bags and high-density polythene bags and vacuum-packed bags stored at room temperature (25 ± 2º C) and cold storage (4 ± 1º C) for a period of 18 months during 2020-21. The treatments having six combinations and consisting of different containers viz., gunny bags, high-density polythene bags, and vacuum-packed bags were replicated four times in both cold and ambient storage conditions in a completely randomized design. The results of the study revealed that the seed quality parameters viz., Seed germination, moisture content and electrical conductivity, seedling length, SVI, and seed physiological parameters such as mineral content (Cu, Mn, Zn and Mn) values were higher in vacuum-packed seeds than gunny, HDPE bags for soybean seeds stored under cold storage compared to room temperature throughout the storage period. Among the containers, the seeds stored in vacuum-packed bags maintained the seed quality and seed physiological parameters with least deterioration compared to seeds stored in gunny bags and high-density polythene bags.

Keywords: *Seed quality, Moisture content, electrical conductivity, mineral content, vacuum packaging, and cold storage.*

Introduction

Soybean [*Glycine max* (L.) Merill] is one of the most important protein and oil seed crops throughout the world. Its oil is the largest component of the world's edible oils. Soybean seed contains 20 % oil and 40 % protein. The world's production of edible oils consists of 30 % soybean. It is an ingredient of more than 50% of the world's high-protein meals. The United States of America has the largest area under soybean cultivation with the highest yield and production [8]. Soybean is globally grown over an area of 91.40 m ha, with a production of 218.00 m tons and productivity of 2455 kg per ha [8].

In India soybean is grown over an area of 9.33 m ha with a production of 9.50 m tons and productivity of 1089 kg per ha which is much below the average productivity of the world (2455 kg/ha). The major soybean-producing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh, and Gujarat. In Karnataka state also, soybean is becoming popular as an oil seed crop. The increase in area was from 0.16 lakh ha during 1991-92 to 1.82 lakh ha during 2019-20 with a production of 1.94 lakh tons and productivity of 1025 kg per ha which is less than the average productivity (1188 kg/ha) of India [8]. Soybean has many commercial applications due to which there has been an increasing demand for seeds to satisfy the expanding producer and consumer market.

*Corresponding Author: **Meena, M. K***
*Email Address: **meenam4565@gmail.com***

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Poor germination and low seed viability are among the serious problems limiting the production of soybean. Storage of seeds at least for the next sowing season is an essential concern of the seed industry.

In agriculture, seed is a vehicle to deliver almost all agro-based technological innovations so that the farmers can exploit the genetic potential of new varieties. The availability, access, and use of seeds of adaptable varieties are, therefore, the major determinants to attain the efficiency and productivity of other packages like irrigation, fertilizers and pesticides. This is one of the vital keys to increasing crop production, enhancing food security and alleviating rural poverty in developing countries. Research on the storability of seeds in India is of recent origin with the development of organized seed production and marketing. It is stipulated that 80 percent of certified seeds produced in India require storage for one planting season and 20 percent of seeds is carried over for subsequent sowing [9]. However, when awareness and infrastructure is developed, a substantial quantity of seeds can be stored for few planting seasons as a safeguard against monsoon failure and as a precaution against the production of poor-quality seeds. Seed deterioration has been ascribed to physical, physiological, biochemical, and pathological detrimental changes occurring in seeds leading to death and has been characterized as inexorable, irreversible, inevitable, and minimal at the time of physiological maturity and variable among kinds of seeds, varieties, and seed lots [9]. The poor storability of the seeds of soybean is accounted for its high oil content, physiological fragility, and thin seed coat, which leads to rapid loss of viability and vigor in storage, which in turn results in the poor establishment of the crop in the field and low productivity. Research concerning to these aspects is very meager. Keeping above these aspects in view and considering their importance in maintaining viability for longer

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period the present investigation was carried out study the seed physiological and biochemical parameters of soybean *(Glycine max) as* Influence by different packaging materials and storage conditions.

Materials and methods

A storage experiment was carried out for a period of 12 months i.e. from October-2021 to October-2022 at the Department of Crop Physiology, University of Agricultural Sciences, Raichur. In this research work, seeds of the soybean variety i.e. JS-335 collected from APMC, Raichur were dried under sun and stored under different storage conditions and containers. The temperature maintained in the cold storage was around (4 °C ± 1°C) and relative humidity was 85 to 90 per cent throughout the storage period while, for ambient storage, bags were stored in the laboratory at room temperature (25 ± 2 °C). Soybean seeds were packed in 500 g vacuum-packed bags and 15 kg to gunny and high-density polythene bags. After packaging of all the seeds in different containers, 50 % bags were stored properly in the iron racks without stacking so that all the bags were uniformly exposed to the particular treatment condition; while 50 % bags were stored under cold storage. The treatments having six combinations and consisting of different containers viz., gunny bags, high-density polythene bags and vacuum-packed bags were replicated four times in both cold and ambient storage conditions in a completely randomized design. The observations on various seed physiological parameters viz., electrical conductivity [58], and the per cent moisture were obtained by using MB 45 Halogen Moisture Analyzer from Ohaus, USA, while estimation of mineral content i.e. Copper (Cu), Zinc (Zn), Iron (Fe) and Manganese (Mn) contents in seed was estimated using Atomic Absorption Spectrophotometer (AAS-4141, Electronic Corporation of India Ltd.) **,** respectively at bimonthly interval upto18 months. The analysis and interpretation of the experimental data were done as suggested by [57] with a level of significance used as P = 0.01.

Results and discussion

Influence on seed quality parameters

Germination (%)

It was revealed from the data (Table 1), that the containers used for storage had a significant effect on soybean seed germination during all the periods of storage. At the beginning of storage, the seed germination was 94.37 percent.Up to 3 months of storage no significant differences between storage container and storage conditions. However, it goes on decreasing with the advancement of storage periods up to 12 months. Regardless of cold storage or room temperature, vacuum-packed seeds maintained a good germination rate throughout the storage process, even up to 12 months. At the end of the storage period (12 months), the germination rate was above 91.88 percent, which is much greater than the minimum seed certification criterion. In cold storage, seeds stored in cloth bags, HDPE bags, and aluminum bags could maintain minimal seed certification criteria for up to 10 to 12 months (75.06, 77.67, and 77.01 %) ,respectively While seeds stored in cloth bags, HDPE bags, and aluminum bags at room temperature could only be kept up to 8 to 10 months (74.11, 77.11and 76.14 %), respectively. At the end of 12 months, the vacuum-packed bags held in cold storage had the highest germination rate (91.88 %), followed by vacuum-packed bags stored in ambient storage (91.65 %). Both, however, did not differ much from one another. Significantly lower germination percent (66.53 %) was observed in cloth bags followed by HDPE bags (68.45 %) stored under ambient storage, which was significantly lower compared to all other treatments. The results show that seed storability is greater in cold storage in cloth, HDPE and aluminum bags than in room-temperature storage. The vacuum-packed seeds can be stored for up to 12 months at room temperature or in cold storage. This is mainly because of the maintenance of lower moisture content (8.52 %) during the storage period. Containers *viz.,* aluminum foil and polyethylene acted as moisture-proof barriers. This is evidenced by lower moisture content (8.52 %) in the seeds packed in vacuum packed seeds. This lower moisture content resulted in a lower respiration rate, lower metabolic activity, and maintenance of higher seed vigour during storage. This is in accordance with the findings of [73] in onion, cabbage, radish, cauliflower, okra, pea and [38] in onion, [70] in sorghum, [65] in groundnut and [68] in sunflower.

Table 1. Influence of packaging and storage conditions on germination (%) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	94.37	91.73	90.34	83.42	74.11	69.85	66.53
T_2 - Cloth bag (CS)	94.37	92.37	90.33	88.68	81.54	75.06	70.75
T_3 - HDPE (RT)	94.37	92.38	91.06	86.98	77.59	70.92	68.42
T_4 - HDPE (CS)	94.37	93.22	91.96	89.37	82.62	77.67	71.73
T_5 - Aluminium bag (RT)	94.37	93.36	92.23	90.45	85.55	76.14	74.18
T_6 - Aluminium bag (CS)	94.37	93.48	92.18	91.31	88.01	79.29	77.01
T_7 - Vaccume bag (RT)	94.37	94.27	94.16	93.61	92.90	91.72	91.65
T_8 - Vaccume bag (CS)	94.37	94.33	94.27	93.99	93.12	92.25	91.88
S.Em(±)	0.50	0.63	0.55	0.54	0.44	0.61	0.49
C. D. (1%)	NS	NS	1.66	1.65	1.33	1.86	1.49

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

2. Moisture content (%)

The moisture content (%) of soybean seeds presented in Table 2 indicated significant differences between the treatments at all the stages of storage upto 12months except at the initial stages (i.e., 0 months). In general, these was no change in the moisture content of vacuum-packed as well as aluminium-packed seeds during storage for 18 months however there was a slight decline in the moisture

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content with progress in the storage time. More fluctuations were seen in the moisture content of soybean seeds stored in cloth bags, irrespective of storage at room temperature or cold storage throughout the storage period.

Among the different packaging materials used in the study, the seeds packed in a vacuum packed bag recorded significantly lower moisture content (9.40 %) which was on par with aluminum bag(11.9 %) and the highest is seeds were packed in cloth bag (15.9%). But better storability of seeds in vacuum packed bag compared to aluminum bag, cloth bags and HDPE bags could be ascribed to the fact that the seeds stored in vacuum polythene bag are moisture impervious and had got very less fluctuations in their moisture content which is a very important factor in maintaining viability of seeds during storage. Lower moisture content of seeds results in lower respiration rate, lower metabolic activity and maintenance of higher seed vigor during storage. This is in accordance with the findings of [64] in French beans. Similar results are also reported by [17] in shelled peanuts, [41] in wheat, [61] in groundnut kernels, [64 in chilli], [32] in soybean, [67] in chili powder, [68] in whole chilli and [46] in soybean storability for a longer period.

Table 2. Influence of packaging and storage conditions on moisture content (%) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	9.30	14.6	14.9	15.1	15.3	15.7	15.9
T_2 - Cloth bag (CS)	9.30	13.2	13.8	14.6	14.7	14.9	15.0
T_3 - HDPE (RT)	9.30	11.4	13.7	14.4	14.6	14.7	14.9
T_4 - HDPE (CS)	9.30	11.5	12.8	13.1	13.4	13.6	13.8
T_5 - Aluminium bag (RT)	9.30	10.6	11.9	12.3	12.6	12.8	12.9
T_6 - Aluminium bag (CS)	9.30	10.8	10.9	11.1	11.5	11.8	11.9
T_7 - Vaccume bag (RT)	9.30	9.36	9.33	9.31	9.32	9.33	9.35
T_8 - Vaccume bag (CS)	9.30	9.41	9.37	9.34	9.35	9.38	9.40
S.Em(±)	0.20	0.16	0.13	0.07	0.09	0.12	0.23
C. D. (1%)	NS	0.45	0.36	0.22	0.25	0.38	0.65

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Electrical conductivity (d Sm^{-1})

The data pertaining to electrical conductivity (d Sm-1) of soybean seeds as influenced by different packaging and storage conditions indicated significant differences upto 12 months of storage period (Table 3). At initial stage (i.e., up to 4 months) there were no significant differences between the treatments but slight increase in electrical conductivity precisely from 4 months onwards and until upto 12months of storage observed in cloth bag seeds stored at room temperature followed by cold storage. While the increase in electrical conductivity of vacuum-packed seeds was much lower than in aluminium-packed seeds at all the stages of storage. At 12 months of storage, significantly higher electrical conductivity values (0.595 and 0.570 dSm-1) were recorded in cloth bag seeds kept at room temperature and cold storage. While significantly lower electrical conductivity values (0.525 and 0.520 d Sm-1) were recorded in vacuum-packed seeds at cold storage and at room temperature followed by aluminium-packed seeds (0.583 and 0.566 d Sm-1), respectively. The similar trend was continued at all the stages of storage months. It is clear from the results that the vacuum-packed seeds could maintain lower electrical conductivity compared to aluminium bags followed by cloth bags during the storage. Vacuum-packed seeds stored in cold storage and room temperature did not show significant differences with each other. While, the cloth bags and the aluminum bags differed significantly to each other throughout the storage period. The values of electrical conductivity of seeds stored different in all the containers at cold storage were recorded lesser than those stored at room temperature throughout the storage period. The electrical conductivity was significantly lower in seeds stored in vacuum-sealed containers followed by aluminum bags and was higher in cloth bags and HDPE bags throughout the storage period. Higher electrical conductivity values recorded in seeds stored in gunny bags and cloth may be due to higher levels of seed deterioration on account of age induced membrane damage of various cell and cell organelles or degradation or disruption of cell membranes leading to subsequent loss of membrane integrity [80] in bittiergourd and [72] in groundnut seeds .At 12 months of storage, vacuum-packed bags and aluminium foil showed significantly lower electrical conductivity, while significantly higher electrical conductivity was found in cloth bags and HDPE bags stored under both ambient and cold storage. Similar results were obtained by [12] and [60] in rice, [53] in brinjal seeds, [39] in cucumbers, [48] in groundnut, [76] in soybean. Similar results were obtained by Biradar Patil *et al.* (1999) and Raiker *et al.* (2011) in rice.

Table 3. Influence of packaging and storage conditions on electrical conductivity (dSm-1) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	0.496	0.505	0.521	0.525	0.528	0.540	0.595
T_2 - Cloth bag (CS)	0.496	0.502	0.519	0.520	0.521	0.532	0.570
T_3 - HDPE (RT)	0.496	0.511	0.516	0.522	0.524	0.536	0.591
T_4 - HDPE (CS)	0.496	0.508	0.513	0.519	0.520	0.531	0.572
T_5 - Aluminium bag (RT)	0.496	0.513	0.515	0.520	0.521	0.533	0.583

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T_6 - Aluminium bag (CS)	0.496	0.510	0.511	0.517	0.518	0.529	0.566
T_7 - Vaccume bag (RT)	0.496	0.504	0.507	0.513	0.519	0.521	0.525
T_8 - Vaccume bag (CS)	0.496	0.502	0.505	0.510	0.516	0.517	0.520
S.Em(±)	0.017	0.037	0.064	0.005	0.008	0.007	0.001
C. D. (1%)	NS	NS	NS	0.014	0.024	0.021	0.003

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Total seedling length (cm)

The data on total seedling length (cm) of seedlings due to the influence of different packaging materials and storage conditions during the storage period is presented in Table 4.

Total seedling length (cm) of soybean seeds differed significantly between thetreatments and reduced from 4 months onwards until up to 12 months of storage incloth bag seeds. The decline in total seedling lengthof vacuum packed seeds was much slower than in high-density polythene and aluminum bag seeds at all thestages of storage.Significantly lower total seedling length values (32.25 and 32.58 cm) were recorded in cloth bag seeds kept under room temperature and cold storage, respectively at 4 months of storage. While, the significantly higher values (33.22 and33.37 cm) were recorded in vacuum packed seeds stored under cold storage room temperature andcold storage followed by aluminium-packed seeds (32.87 and 33.07 cm) and high-density polythene seeds (32.59 and 32.81 cm), respectively. A similar trend continued at all the stages of storage upto 12 months.

At the end of storage period, vacuum-packed seeds recorded significantly highervalues (32.26 and 32.81 cm) kept under cold storage and room temperature,respectively compared to aluminum bag seeds (29.58 and 29.99 cm), high-density polythene seeds (27.24 and 29.62 cm)and cloth bags(29.58 and 29.99 cm). It is clear from the results that the vacuum packed seeds could maintain higher value compared to aluminum bags followed by high-density polythene and cloth bags throughout the storage period. It is also clear that within the treatments, there was no significant difference in vacuum packed seeds either stored under cold storage or room temperature; while the cloth bags, high density polyethylene and aluminum bags differed significantly with each other throughout the storage period. The reduction in total seedling length is always greater in moisture-pervious containers like cloth bag and high density polythene bag, which is mainly due to increased seed deterioration. Decline in total seedling length during storage were also recorded by other workers [69] in paddy; [75] . Similarly, the superiority of moisture-impervious containers in producing longer root length and shoot length of groundnut seedlings has been reported by [40] in grount seeds and [18] in greengram.

Table 4. Influence of packaging and storage conditions on total seedling length (cm) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	33.43	32.41	32.25	31.19	29.66	28.41	26.68
T_2 - Cloth bag (CS)	33.43	32.73	32.58	31.33	30.58	29.36	28.66
T_3 - HDPE (RT)	33.43	32.89	32.59	31.54	30.27	28.10	27.24
T_4 - HDPE (CS)	33.43	33.00	32.81	31.81	30.83	30.25	29.62
T_5 - Aluminium bag (RT)	33.43	33.01	32.87	31.85	30.90	30.36	29.58
T_6 - Aluminium bag (CS)	33.43	33.22	33.07	32.14	31.64	30.74	29.99
T_7 - Vaccume bag (RT)	33.43	33.26	33.22	32.93	32.65	32.54	32.26
T_8 - Vaccume bag (CS)	33.43	33.46	33.37	33.17	33.12	32.94	32.81
S.Em(±)	0.29	0.22	0.13	0.04	0.08	0.12	0.05
C. D. (1%)	NS	NS	NS	0.87	0.94	0.48	0.33

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Seedling vigor index (SVI)

The influence of different packaging and storage conditions on the seedling vigour index indicated significant differences between the treatments (Table 5).The decline in seedling vigour index from 4 months onwards and until upto 12 months of storage in cloth bag seeds. Further, the decline in seedling vigour index of vacuum-packed seeds was much lesser followed by aluminium packed seeds and high density polythene at all the stages of storage. At 4 months of storage, significantly lower seedling vigour index (2913.51 and 2942.84) was recorded in cloth bag seeds stored under either room temperature or cold storage. While significantly higher seedling vigour index (3127.88 and 3148.68) was recorded in vacuum packed seeds stored under room temperature and cold storage followed by aluminium-packed seeds (3031.67 and 3048.45) and high-density polythene (2967.50 and 3008.24), respectively. At the end of storage period, vacuum packed seeds recorded significantly higher seedling vigour index (3002.12 and 2916.22) kept at cold storage and room temperature compared to aluminum bags (2639.53 and 2490.18) as well ashigh density polythene (2124.78 and 1863.81) and cloth bags (2027.60 and 1775.11),respectively. It is clear from the results that the vacuum-packed seeds could be maintained a higher seedling vigour index compared to aluminum bags followed byhigh density polythene and cloth bags the whole time of the storage period. It is also clear from the results that no significant differences were found between vacuum packed treatment, while clothbags, high-density polythene bags and aluminum bags differed significantly with each other throughout the storage period. . Similarly, the superiority of moisture-impervious containers in producing longer root length and shoot length of groundnut seedlings has been reported by [40] in grount seeds and [18] in greengram.

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Table 5. Influence of packaging and storage conditions on seedling vigor index (SVI) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	3154.68	2972.97	2913.51	2601.77	2286.79	2012.75	1775.11
T_2 - Cloth bag (CS)	3154.68	3023.16	2942.84	2778.38	2492.27	2203.76	2027.60
T_3 - HDPE (RT)	3154.68	3038.38	2967.50	2743.30	2255.12	1992.95	1863.81
T_4 - HDPE (CS)	3154.68	3076.37	3008.24	2842.75	2546.56	2349.52	2124.78
T_5 - Aluminium bag (RT)	3154.68	3081.81	3031.67	2880.73	2765.55	2615.11	2490.18
T_6 - Aluminium bag (CS)	3154.68	3105.41	3048.45	2934.81	2847.92	2744.67	2639.53
T_7 - Vaccume bag (RT)	3154.68	3135.42	3127.88	3049.54	3033.19	2948.77	2916.22
T_8 - Vaccume bag (CS)	3154.68	3154.05	3148.68	3094.43	3053.33	3029.74	3002.12
S.Em(±)	34.5	25.6	18.7	29.3	25.1	19.5	20.4
C. D. (1%)	NS	NS	NS	33.3	34.6	50.1	51.4

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Mineral content (Cu, Zn, Fe, and Mn (mg/kg))

The observation on mineral content (mg/g) of soybean seeds as influenced by different packaging and storage conditions (Table 6, 7, 8 and 9) exhibited significant differences at all the stage period. There was a decline in Cu, Zn, Fe and Mn content from 4th months and continued upto 12 months of storage in cloth, HDPE and aluminium bag seeds stored under room temperature. On the other hand, the decline in mineral content of vacuum-packed seeds was much lesser and slower than in cloth, HDPE and aluminiumbag seeds at all the stages ofstorage either kept under cold storage or room temperature. Among the treatments, thecopper content did not differ significantly upto 10 months of storage but at end the of storage upto12 months; a significant difference was observed in all the treatments irrespective of cold storage or room temperature.At 12 months of storage, significantly lower mineral content Cu (11.89 and 12.10), Zn(44.01 and 45.03), Fe(101.01 and 101.23) and Mn (26.11 and 26.21) mg/kg) was recorded in cloth bag seeds kept under room temperature and cold storage. Significantly higher mineral content (Cu (13.12 and 13.16), Zn(45.15 and 45.21), Fe(102.17 and 102.24) and Mn (26.90 and 26.93) mg/kg)were recorded in vacuum packed seeds stored under cold storage and room temperature. Variations in the mineral contents between the packaging materials could be attributed to the redistribution of mineral elements in seeds and possible microbial contamination [14]. In the polythene bags mineral content values were higher than cloth and gunny bags, but it was lower than vacuum packed bags. Same results were obtained by [28] in groundnut, [68], in melon seeds, [25] in cocoyam chips, [43] and [22] in chilli.Higher mineral contents during cold storage compared to ambient storage could be attributed due to lower internal physiological and biochemical processes in the seed thereby prolonging the shelf life of seeds during storage. Higher micronutrients in vacuum-packed bags compared to gunny bags, may be due to a decrease in ash content [35] Similar findings were also reported in shelled melon seeds [39] millet seeds [26] okra [27] and greenbean [57] in apple fruits seeds.

Table 6. Influence of packaging and storage conditions on copper content (Cu, mg/kg) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	13.61	12.23	12.01	11.97	11.93	11.92	11.89
T_2 - Cloth bag (CS)	13.61	12.46	12.23	12.20	12.18	12.14	12.10
T_3 - HDPE (RT)	13.61	12.39	12.16	12.14	12.09	12.03	12.01
T_4 - HDPE (CS)	13.61	12.65	12.43	12.38	12.31	12.26	12.23
T_5 - Aluminium bag (RT)	13.61	13.10	12.63	12.61	12.59	12.52	12.42
T_6 - Aluminium bag (CS)	13.61	13.21	12.71	12.68	12.60	12.55	12.49
T_7 - Vaccume bag (RT)	13.61	13.51	13.40	13.31	13.22	13.18	13.12
T_8 - Vaccume bag (CS)	13.61	13.57	13.45	13.37	13.26	13.21	13.16
S.Em(±)	0.11	0.46	0.48	0.67	0.76	0.36	0.45
C. D. (1%)	NS	NS	NS	NS	NS	1.04	1.29

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Table 7. Influence of packaging and storage conditions on iron content (Fe, mg/kg) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	102.92	101.42	101.10	101.07	101.05	101.03	101.01
T_2 - Cloth bag (CS)	102.92	101.72	101.49	101.38	101.31	101.28	101.23

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T_3 - HDPE (RT)	102.92	101.48	101.20	101.18	101.15	101.14	101.06
T_4 - HDPE (CS)	102.92	101.65	101.32	101.23	101.19	101.17	101.11
T_5 - Aluminium bag (RT)	102.92	101.92	101.30	101.27	101.23	101.20	101.15
T_6 - Aluminium bag (CS)	102.92	102.10	101.97	101.68	101.55	101.49	101.33
T_7 - Vaccume bag (RT)	102.92	102.43	102.34	102.27	102.22	101.20	102.17
T_8 - Vaccume bag (CS)	102.92	102.51	102.41	102.35	102.30	102.28	102.24
S.Em(±)	0.41	0.58	0.65	0.78	0.05	0.07	0.06
C. D. (1%)	NS	NS	NS	NS	0.16	0.22	0.17

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Table 8. Influence of packaging and storage conditions on magnesium content (Mg, mg/kg) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	27.27	26.92	26.51	26.31	26.22	26.14	26.11
T_2 - Cloth bag (CS)	27.27	27.10	26.60	26.40	26.31	26.28	26.21
T_3 - HDPE (RT)	27.27	27.01	26.67	26.52	26.49	26.41	26.38
T_4 - HDPE (CS)	27.27	27.11	26.69	26.58	26.52	26.49	26.41
T_5 - Aluminium bag (RT)	27.27	27.20	27.10	27.00	26.92	26.88	26.79
T_6 - Aluminium bag (CS)	27.27	27.21	27.11	27.03	27.01	26.91	26.83
T_7 - Vaccume bag (RT)	27.27	27.23	27.19	27.11	27.01	26.95	26.90
T_8 - Vaccume bag (CS)	27.27	27.25	27.21	27.17	27.04	27.01	26.93
S.Em(±)	0.18	0.33	0.31	0.34	0.37	0.40	0.04
C. D. (1%)	NS	NS	NS	NS	NS	NS	0.12

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Table 10. Influence of packaging and storage conditions on zinc content (Zn, mg/kg) at different time intervals of storage in soybean seeds

Treatments	Storage period (months)						
	0	2	4	6	8	10	12
T_1 - Cloth bag (RT)	46.22	45.51	44.23	44.19	44.11	44.07	44.01
T_2 - Cloth bag (CS)	46.22	45.89	45.46	45.28	45.20	45.15	45.03
T_3 - HDPE (RT)	46.22	45.63	44.89	44.47	44.39	44.21	44.14
T_4 - HDPE (CS)	46.22	45.91	45.15	44.98	44.84	44.62	44.55
T_5 - Aluminium bag (RT)	46.22	46.10	45.41	44.27	44.20	44.18	44.05
T_6 - Aluminium bag (CS)	46.22	46.15	45.56	45.33	45.22	45.16	45.13
T_7 - Vaccume bag (RT)	46.22	46.16	45.83	45.71	45.37	45.21	45.15
T_8 - Vaccume bag (CS)	46.22	46.20	45.91	45.78	45.54	45.33	45.21
S.Em(±)	0.36	0.55	0.59	0.53	0.71	0.73	0.17
C. D. (1%)	NS	NS	NS	NS	NS	NS	0.50

HDPE - High density polythene CS - Cold storage
NS - Non significant RT - Room temperature

Conclusion

Seed physiological and biochemical parameters deterioration is an inexorable and irreversible process. The quality and viability of soybean seeds are subjected to variations during storage conditions and it has been found that the life span of seeds depends on the moisture content of the seeds, relative humidity, temperature, light, and oxygen content under which the seeds are stored. It has been found in the present study that it is possible to extend the shelf life of soybean seed's up to18 months without deterioration in seed quality parameter's *viz.,*seed germination , EC, moisture content, seedling length, SVI, while seed physiological parameters such as mineral content (Cu, Mn, Zn and Mn), moisture content and electrical conductivity by storing them under vacuum packaging. Since seed is an important input in agriculture which determines not only the production but also the productivity, it is essential to maintain the seed quality as well as seed vigor.

Future scope of study: The strategies for future research and development to improve the investigation on influence of vacuum packaging on seed physiology and quality of soybean crops has thrown light on several aspects that need to be worked at in detail in the future. To enumerate the more probable ones; the storage studies can further be extended beyond 18 months to know the influence of vacuum packaging and storage conditions on other field crop seeds *viz*., vegetables, pulses, oil seeds under both ambient and cold storage. There is a scope for evaluating some more storage containers, which are

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domestically available in rural areas such as earthen pots, polythene lined gunny bags and also similar storage studies may be conducted on other agricultural as well as on horticultural crops. Vacuum packaging technology has huge potential and therefore it needs to be explored for different dehydrated products, food grains and other dry spices and food products, so that post harvest losses can be minimized to a greater extent and food hygiene can be maintained.Studies can also be directed towards the use of oxygen scavenger films while packing and its influence on long term storage in different food commodities.There is need to study the combined effect of vacuum packaging and use of oxygen scavengers. Measures to eliminate oxygen from the pack may be taken up. The use of active packaging methods like use of oxygen absorbents may be resorted to. The study has revealed that to oxidation occurred in vacuum packed bags to a similar extent. It is therefore imperative that work needs to be taken upto to quantify the amount of oxygen as well as carbon dioxide in the package, so that appropriate measures can be taken to avoid oxidation.

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