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Effect of Storage Environment and Packaging Materials in Groundnut Seeds (*Arachis hypogaea* L.)

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ABSTRACT: Groundnut seeds are prone to deterioration during storage. The quality of seeds after harvest is crucial for successful seed production and long-term use, especially for improving crop yields. Numerous factors, including genetic, edaphic, environmental, and biotic, influence the quality of seeds. Maintaining high-quality seed is necessary to create complex environments that encourage the most favorable interactions between the genetic composition of the seed and the surroundings in which it is grown, harvested, processed, and stored. Seeds lose some of their vigor and germination during storage due to deterioration. In light of this, the current study to understand the physiological and biochemical changes that occur in groundnut seeds under different storage conditions and packaging materials was conducted at Department of Crop Physiology, University of Agricultural sciences, Raichur, India. Groundnut seeds were stored in different packaging materials *viz*., gunny bags, cloth bags, high density polythene bags, purdue improved crop storage bags and vacuum packed bags and stored at ambient and cold conditions (5-7 °C and 65-70 % RH) for a period of 18 months. The results of the study revealed that seeds stored in vacuum packed bags maintained the highest seed quality parameters compared to seeds packed in gunny bags, cloth bags, high density polythene bags and purdue improved crop storage bags after 18 months of storage. These parameters included germination (89.61 % and 35.66 %), mobilization efficiency (17.97 % and 10.41 %), seedling dry weight (682 mg and 361 mg), moisture content (6.61 % and 9.91 %), dehydrogenase activity (1.46 and 1.01 OD values) and lipase activity (0.325 and 0.676 milliequivalent free fatty acid/min/g). Therefore, the study concluded that seeds stored in vacuum packed bags are the best options for storing groundnut seeds for up to 18 months without compromising their viability.

Keywords: Seed storage, seed quality, mobilization efficiency.

INTRODUCTION

Groundnut, also known as peanut, is a legume or bean crop that ranks third in global oilseed production. It has various local names around the world, such as monkey nuts, ground nuts, goober peas, earthnuts, and pygmy nuts. Groundnut seeds are semi-perishable, which means they can lose their quality over time due to different factors. Some of these factors are biotic, such as insects, rodents, and fungi, while others are abiotic, such as rancidity, viability loss, shrinkage, and weight loss. Therefore, groundnut seeds need proper storage conditions to preserve their quality. The quality and shelf life of groundnut seeds depend on various factors that affect their storage. Some of these factors are intrinsic, such as moisture content, variety, and composition of the seeds, while others are extrinsic, such as temperature, relative humidity, storage structure, and packaging system. One of the most important factors for storage is moisture content. Groundnut seeds have high moisture content when they are harvested from the soil. The moisture content must be reduced to a safe level (8–10 %) as soon as possible after harvest to prevent spoilage and deterioration. To improve the storability of groundnut seeds, some advanced techniques can be used, such as vacuum packaging. This technique can extend the shelf life of food products by preventing the entry of oxygen inside the package. Vacuum packaging is a technique that involves placing items in a plastic film, either manually or automatically, and then removing the air from the package before sealing it. This technique can reduce the oxygen level and prevent the growth of aerobic microorganisms and oxidation reactions. This results in reduced microbial growth and improved hygiene by minimizing the risk of cross contamination. A decrease in quality parameters of onion, cotton, soybean and peanut seed was observed during 18 months of storage period compared to vacuum stored seeds. According to Nithya and Renugadevi (2017) the groundnut seeds stored at -20 ºC with 6 per cent moisture content maintained the seed physiological qualities like germination and vigour index at higher level with minimum loss in biochemical parameters like protein and oil content and less reduction in the activities of enzymes than the seeds under ambient storage. Storing groundnut seeds in poor or unfavourable environmental conditions causes a major issue known as seed degradation or deterioration, which is characterised by a loss of viability. Vacuum sealing seeds in a freezer can extend their shelf life for long-term storage and also preserve the physical and biochemical quality of chilli seeds better than jute bags (Deepa *et al.*, 2013). Ballesteros *et al.* (2021) indicate that vacuum sealing is not optimal for some types of seeds, such as recalcitrant seeds, which are sensitive to desiccation. Vacuum packaging improved the quality and viability of peanuts as showed by Meena *et al.* (2017). They measured germination, root length, shoot length, seedling vigor index and relative conductivity found that vacuum packaged samples had maintained for all parameters except relative conductivity, which was lower than the gunny and HDPE bag. Groundnut is a crop that is mainly grown by small farmers who lack the proper facilities to store and protect their harvest. The rainy season can cause moisture accumulation and mycotoxin contamination in the stored pods, which affects their quality and safety. Furthermore, the demand for edible oils has increased significantly in recent years, but the supply of oilseeds has not kept up. Therefore, it is important to find ways to preserve the availability of groundnuts in winter, especially for the spring-grown crop. The aim of this study was to evaluate how different packaging materials can influence the quality and shelf life of groundnut seeds. The study also sought to identify the most suitable packaging materials for storing groundnut seeds.

MATERIAL AND METHODS

The study was conducted at the Department of Crop Physiology, University of Agricultural Sciences, Raichur, for 18 months from October-2019 to June-2022. Groundnut seeds variety TMV-2 were freshly harvested were sun-dried and stored in different environment and containers. The experiment had a 5 × 2 × 9 factorial structure and used a complete randomised design (CRD) with three replications to test 90 treatment combinations, which were formed by combining five types of packaging materials (Gunny bag, cloth bag, high density polythene bag, perdue improved crop storage bag and vacuum packed bag) with two storage environment (ambient and cold storage (5-7ºC and 65-70 % RH) and nine storage period (2, 4, 6, 8, 10, 12, 14, 16 and 18 months). Groundnut seeds (3 kg) were weighed before being packed in to gunny bag, cloth bag, high density polythene bag, purdue improved crop storage bag and 500 g was packed in vacuum packed bag. Vacuum packaging was done using vacuum packaging machine (VAC-STAR S-220 MP 400/kW manufactured by ROUTE DE I'INDUSTIRIES, CH-1786, Sugiez, Switzerland.).

Determination of physico-biochemical parametrs of groundnut seeds during storage

Germination percentage. The germination test was carried out in four replications of 100 seeds in each treatment, with the temperature in the germinator kept at 25 ± 1 ºC and 90 % RH according to ISTA regulations (Anon., 2013). The germination count on normal seedlings was taken on 10th day for groundnut. The average of four replications was measured and expressed in percentage.

Mobilization efficiency. Mobilization efficiency is defined as mobilization and utilization of food reserves during seed germination. Seeds with higher food reserves are known to produce vigorous seedling owing to better capacity to supply food materials to seedlings. It also depends on species, size of seed and food reserves. It was calculated by the following formula (Srivastava and Sareen 1974)

$$\text{Mobilization efficiency (\%)} = \frac{\text{Dry weight of seedlings}}{\text{Dry weight of seeds}} \times 100$$

Dry weight of seedling. Ten seedlings used for measuring the seedling length were utilized for determining the dry weight of the seedlings. Seedlings were dried in hot air oven maintained at 70 ± 1°C for 24 hours. After drying, seedlings were kept in desiccators for cooling and further weighed and expressed in milligrams.

Seed moisture content. It was determined by gravimetric method using low constant temperature hot air oven method as per the procedure given in the ISTA rules (Anon., 1996). Five grams of seeds were taken in sample cups. Seeds were dried at low constant temperature, maintained at 103 ± 1 ºC for 17 ± 1 hour and then dry weight of seed material along with cups was noted. The moisture content was determined on wet weight basis by using the formula:

$$\text{Seed moisture content (\%)} = \frac{(M_2 - M_3)}{(M_2 - M_1)} \times 100$$

Where,

M_1 = Weight of the empty container (g), M_2 = Weight of container with seed sample before drying (g), M_3 = Weight of container with seed sample after drying (g)

Determination of lipase enzyme activity.

Substrate solution: For preparation of substrate solution, 2.0 ml of castor oil was taken into conical flask, which was neutralized to pH 7.0 and stirred well with 25 ml of distilled water in presence of 100 mg of bile salts (sodium taurocholate) till an emulsion was formed. Then 2.0 g of gum acacia powder was added to hasten emulsification.

Preparation of enzyme source: One gram of water-soaked seeds was taken and ground in a mortar and pestle. Grinding was continued by adding distilled water in a proportion of 5 ml every time. The suspension was then homogenized and centrifuged at 15000 rpm at 4 º C for 10 minutes. Three layers were formed, of which, the upper creamy layer was carefully separated and used as enzyme source.

Exactly 25 ml of 0.1 M phosphate buffer (pH 7.0) was taken into a conical flask, containing 5.0 ml of substrate solution, to which 2.0 ml of enzyme solution was added. The reaction mixture was incubated at 37 ºC for one hour. After exactly one hour, 5.0 ml each of ethanol and ether were added to stop the reaction. Finally, one drop of phenolphthalein indicator was added to the mixture and titration was carried out against 0.1N NaOH till pink colour was obtained. Similarly, a blank titration was done against 0.1N NaOH by adding equal volume of distilled water in place of enzyme source. The enzyme activity was calculated by the following formula and expressed as µ moles min^{-1} (Jayaraman, 1981).

$$\text{Lipase enzyme activity} = \frac{\text{Volume of alkali consumed} \times \text{Strength of alkali}}{\text{Wt. of sample in (g)} \times \text{Time in min}}$$

Dehydrogenase activity. 5 gram of seeds from the representative samples were taken and preconditioned by soaking in water for 24 hours at room temperature and seed embryos were excised. The embryos are steeped in 1 % solution of 2, 3, 5-triphenyl tetrazolium chloride (TTC) and kept in dark for 18 hours at room temperature. The stained seeds are thoroughly washed with water and then soaked in 5 ml of 2-methoxy ethanol and kept overnight for extracting the red colour formazon. The intensity of red colour was measured using Spectrophotometer and 2-methoxy ethanol taken as the blank. The OD value obtained at 480 nm is documented as dehydrogenase activity and expressed in terms of absorbance (Kittock and Law 1968).

RESULTS AND DISCUSSION

The germination percentage of groundnut seeds varied significantly for the seed obtained from all treatments. The mean germination percentage for cold storage (78.60 %) was significantly higher than the ambient storage (75.04 %). Among the packaging materials, the germination percentage was significantly highest in vacuum packed bag (92.09 %) and lowest in gunny bag (69.60 %). Although there was no significant decrease in mean germination percentage at 2 (93.50 %) and 4 months (92.78 %) of storage however, germination percentage decrease significantly at 18 months (54.27 %) of the storage. The interaction effect between storage condition, packaging materials and storage period revealed that the seeds stored under cold condition and packed in vacuum packed bag (C_2P_5) recorded the significantly highest germination (89.61 %), while the lowest germination was observed in seeds stored under ambient condition and packed in gunny bag (C_1P_1), cloth bag (C_1P_2), HDPE bag (C_1P_3) and PICS bag (C_1P_4) (35.66, 37.58, 40.59 and 47.46 %, respectively) at end of the storage period. The superiority of these packaging materials in maintaining seed germinability for longer period might be due to inverse relationship between seed moisture content and germination percentage (Tiwari *et al*., 2022). Decrease in the moisture content of seeds maintains higher germination during storage by reducing respiration rate and metabolic activity (Sharma *et al.*, 2023). The present findings confirmed the reports of previous workers Padma and Muralimohan Reddy (2000), Ashok *et al.* (2019) in onion and Khalequzzaman *et al*. (2012) in French bean. Similar results of maintaining the seed viability and vigour for a longer period by storing them in vacuum packaging has been reported by Tripathi and Lawande (2014) in onion, Meena *et al.* (2017a) and (2017b) in cotton and groundnut, Wang *et al.* (2018) in rice, Ramya *et al.* (2018) in sesame.

Maximum mean seedling dry weight was significantly higher with seeds stored in cold condition (637 mg) than with seeds stored in ambient condition (C_1) (615 mg). Among the five packaging materials, the highest seedling dry weight was recorded with seeds packed in vacuum packed bag (706 mg). While, the minimum mean seedling dry weight (578 mg) was found with seeds packed in gunny bag followed by cloth bag (599 mg), HDPE bag (618 mg) as compared with PICS bag (627 mg). The least significant differences were observed in seeds stored under cold condition and packed in vacuum packed bag (C_2P_5) recorded 682 mg and seeds stored under ambient condition and packed in vacuum packed bag (C_1P_5) recorded 677 mg at the end of storage period. At end of the storage period, Lower seedling dry weight was recorded in seeds stored under ambient condition and packed in gunny bag (C_1P_1) (361 mg), cloth bag (C_1P_2) (369 mg), HDPE bag (C_1P_3) (376 mg) and PICS bag (C_1P_4) (402 mg).

Storage period exhibited the significant decline in the mobilization efficiency of groundnut seeds. The decrease in mean mobilization efficiency from 18.59 % at 2 months of storage to 12.95 % at the 18 months of storage period. The significantly highest mean mobilization efficiency (16.68 %) was recorded in cold condition compared to ambient condition (16.04 %). Among the packaging materials, the significantly decreased mean mobilization efficiency (15.18) was recorded in gunny bag, which was comparable with cloth followed by HDPE and PICS bag (15.74, 16.17 and 16.40 %, respectively) while, higher mean mobilization efficiency (18.32 %) was noticed in the vacuum packed bag. Interaction effects due to storage conditions, packaging materials and storage months showed significant differences. The significantly highest mobilization efficiency (17.97 %) was recorded in seeds stored under cold condition and packed in vacuum packed bag (C_2P_5) and lowest was recorded in seeds stored under ambient condition and packed in gunny bag (C_1P_1) (10.41 %) after 18 months of storage period. The mobilization efficiency, which is the ability of seedlings to convert their food reserve into a usable form for energy and metabolism. The mobilization efficiency decreases as the seeds age, because the ageing process damages the enzymes that are responsible for this conversion. Therefore, the seedling-associated parameters, such as germination rate, seedling vigour, and seedling length, are reduced by ageing. Results in this study were found similar with the observations made by Meena *et al.* (2017c) in soybean, Ramya *et al.* (2018) in sesame, Ashok *et al.* (2019) in onion and Wawrzyniak *et al.* (2022) in oak.

The observations on seed moisture content of groundnut at differed treatments and their interaction up to 18 months of storage presented in Table 1 and 2. Under ambient condition, there was a fluctuation in moisture content of seeds based on surrounding environmental condition in gunny bag, cloth bag, HDPE bag and PICS bag but not in vacuum packed bag. Significantly maximum mean seed moisture content (10.13 %) was found in ambient condition compared to cold condition (9.46 %). Gunny bag had significantly highest mean seed moisture content (10.54 %) followed by cloth, HDPE, and PICS bag (10.41, 10.24 and 10.03 %, respectively). However, the vacuum packed bag (P_5) had significantly lowest mean seed moisture content (7.74 %). Interaction effects due storage conditions, packaging materials and storage months showed non-significant difference in the seed moisture content. However, numerically lowest seed moisture content (7.69 %) was recorded in cold condition with seeds packed in vacuum packed bag (C_2P_5) compared to ambient condition and stored in gunny bag (C_1P_1) (11.20 %) after 18 months of storage period. Seeds have the ability to take up and release moisture depending on the environmental conditions they are exposed to. When seeds are stored in packaging materials that allow air and moisture to pass through, such as cloth bags, gunny bags, or HDPE bags, their hygroscopicity causes their moisture content to vary. However, when seeds are stored in packaging materials that prevent air and moisture from entering or escaping, such as vacuum-packed bags, aluminium foil, or PICS bags, their hygroscopicity does not affect their moisture content. This means that the moisture content of seeds remains constant when they are stored in impervious packaging materials. Similar findings of no change in seed moisture content when vacuum-packed have been reported by previous studies on chili (Deepa *et al.*, 2013); Chickpea (Khanna *et al.*, 2017) soybean (Meena *et al.*, 2017c) and rice (Assaye *et al.*, 2023).

The dehydrogenase activity of groundnut seeds varied significantly between treatments and decreased gradually as the storage period progressed. The seeds stored in cold condition had the maximum mean dehydrogenase activity (1.256) compared to ambient condition (1.169). Among the packaging materials, seeds stored in gunny bag recorded lowest mean dehydrogenase activity (1.141), which was equivalent to cloth bag, HDPE bag, and PICS bag (1.159, 1.185 and 1.202, respectively) and highest was recorded in vacuum packed bag (1.375). Interaction effects of storage conditions, packaging materials and storage months showed non-significant difference in the dehydrogenase activity. However, numerically highest dehydrogenase activity (1.293) was recorded in seeds stored under cold condition and packed in vacuum packed bag (C_2P_5) and the lowest was observed in seeds stored under ambient condition and packed in gunny bag (C_1P_1) (0.745) at 18 months of storage. Decrease in dehydrogenase enzyme activity might be related to age-induced deterioration which is a common phenomenon in any living entity. The reduction of dehydrogenase activity was due to the inability of the seed tissues to reduce tetrazolium chloride to insoluble formazan as revealed by Raja (2003) in paddy, Arun *et al.* (2021) in cowpea and Rao *et al.* (2023) in soyabean. Similar results of higher reduction of dehydrogenase in pervious packaging material have been reported by Vasudevan *et al.* (2014) in groundnut, Amruta *et al.* (2015) in blackgram, Kumar *et al.* (2017) in alfalfa, Feda *et al.* (2018) in onion, and lesser rate of decrease in dehydrogenase activity in vacuum packed bag has been reported by Ashok *et al.* (2019) in onion.

The seeds stored in ambient condition had the maximum mean lipase activity (0.438 milliequivalent free fatty acid/min/g) compared to cold condition (0.390 milliequivalent free fatty acid /min/g). Seeds stored in gunny bag had highest mean lipase activity (0.453 milliequivalent free fatty acid /min/g) which was on par with seeds stored in cloth bag, HDPE bag, and PICS bag (0.443, 0.435 and 0.424 milliequivalent free fatty acid /min/g, respectively) however, the vacuum packed bag had a lowest mean lipase activity (0.315 milliequivalent free fatty acid /min/g). Interaction effects of storage conditions, packaging materials and storage months showed significant difference in the lipase activity. However, significantly lowest lipase activity (0.325 milliequivalent free fatty acid /min/g) was recorded in cold condition with seeds packed in vacuum packed bag (C_2P_5) compared to ambient condition and stored in gunny bag (C_1P_1) (0.676 milliequivalent free fatty acid /min/g) after 18 months of storage period. Urban Alandete (2019) found that the improper storage of oil-rich seeds accelerates lipid degradation reactions (Grebenteuch *et al.*, 2021; Sun *et al.*, 2022). This is due to the activity of lipase and lipoxygenase enzymes or lipid peroxidation, which negatively impacts food products, increases oil acidity, and leads to a high content of free fatty acids (Shi *et al.*, 2020; Meriles *et al.*, 2022). A decrease in oil content could be attributed to an increase in lipase activity during storage. However, the deterioration rate was found to be lower in cold conditions. Similar findings were observed by Chaitanya *et al.* (2000) in their study on *Shorea robusta* and by Naik (2013) in their research on rice.

Table 1: Mean germination, seedling dry weight, mobilization efficiency, moisture content, dehydrogenase activity and lipase activity, as influence by storage environment, packaging materials and storage periods.

Treatment	Germination	Seedling dry weight	Mobilization efficiency	Moisture content	Dehydrogenase	Lipase
Storage conditions (C)						
Ambient storage	75.04	615	16.04	10.13	1.169	0.438
Cold storage	78.60	637	16.68	9.46	1.256	0.390
Packaging materials (P)						
Gunny bag	69.62	578	15.18	10.54	1.141	0.453
Cloth bag	71.84	599	15.74	10.41	1.159	0.443
HDPE bag	73.27	618	16.17	10.24	1.185	0.435
PICS bag	77.23	627	16.40	10.03	1.202	0.424
Vacuum packed bag	92.09	706	18.32	7.74	1.375	0.315
Storage month (M)						
Month 2	93.50	719	18.59	9.41	1.450	0.312
Month 4	92.78	714	18.45	9.20	1.873	0.321
Month 6	88.88	687	17.92	9.41	1.364	0.342
Month 8	81.15	647	17.02	9.63	1.322	0.361
Month 10	76.63	606	15.99	10.29	1.258	0.414
Month 12	73.20	591	15.47	10.12	1.174	0.469
Month 14	69.05	570	15.15	10.04	1.090	0.519
Month 16	61.95	534	14.83	9.89	0.974	0.537
Month 18	54.27	465	12.95	10.14	0.893	0.564
Interactions						
S × P	**	**	**	**	**	**
S × M	**	**	**	**	**	**
P × M	**	**	**	**	**	**
S × P × M	**	**	**	ns	ns	**

**Significant; ns- non significant; HDPE- High density polythene bag PICS- Perdue improved crop storage bag

Table 2: Influence of packaging materials, storage environment and storage period on physiological and biochemical parameters of groundnut seeds.

	Treatment	Storage month (M)								
		2	4	6	8	10	12	14	16	18
Germination	$C_1 \times P_1$	92.05	90.37	82.05	73.36	68.40	65.71	58.52	42.53	35.66
	$C_1 \times P_2$	92.65	91.34	82.77	74.68	69.32	66.63	60.64	50.85	37.58
	$C_1 \times P_3$	93.41	92.57	84.28	75.11	69.83	67.95	61.21	55.76	40.59
	$C_1 \times P_4$	93.64	93.05	90.17	81.83	75.94	69.56	64.32	59.35	47.46
	$C_1 \times P_5$	94.20	94.03	93.89	92.13	91.40	90.75	90.43	89.56	88.38
	$C_2 \times P_1$	93.33	93.05	88.86	76.43	70.06	67.28	63.70	50.24	43.31
	$C_2 \times P_2$	93.38	93.15	89.97	77.58	94.24	67.52	65.51	56.90	48.47
	$C_2 \times P_3$	94.02	93.22	90.50	78.51	75.37	68.10	66.10	60.44	51.91
	$C_2 \times P_4$	94.16	93.91	92.28	88.95	79.22	76.78	68.55	63.21	57.83
	$C_2 \times P_5$	94.23	94.17	94.03	92.55	92.50	91.71	91.48	90.74	89.61
Seedling dry weight	$C_1 \times P_1$	712	701	659	549	519	510	477	370	361
	$C_1 \times P_2$	718	711	665	583	544	526	497	477	369
	$C_1 \times P_3$	719	716	682	659	626	567	544	482	376
	$C_1 \times P_4$	721	717	693	665	641	571	556	491	402
	$C_1 \times P_5$	723	721	712	709	701	699	693	685	677
	$C_2 \times P_1$	716	710	661	574	564	564	525	522	419
	$C_2 \times P_2$	716	711	677	653	582	582	558	527	436
	$C_2 \times P_3$	720	713	697	674	588	588	575	544	448
	$C_2 \times P_4$	725	720	706	690	645	598	580	551	461
	$C_2 \times P_5$	725	723	723	715	702	702	699	695	682
Mobilization efficiency	$C_1 \times P_1$	18.42	18.20	17.28	15.04	14.19	14.16	13.57	10.58	10.41
	$C_1 \times P_2$	18.56	18.41	17.57	15.63	14.50	14.11	14.32	13.62	10.63
	$C_1 \times P_3$	18.58	18.50	17.80	17.31	15.60	15.42	15.27	13.77	10.81
	$C_1 \times P_4$	18.62	18.53	18.01	17.44	15.75	15.66	15.34	13.98	12.03
	$C_1 \times P_5$	18.65	18.60	18.44	18.36	18.23	18.16	18.13	18.00	17.86
	$C_2 \times P_1$	18.51	18.39	17.34	15.41	15.36	15.18	14.69	14.67	11.92
	$C_2 \times P_2$	18.51	18.40	17.68	17.16	15.81	15.58	15.56	14.81	12.37
	$C_2 \times P_3$	18.60	18.51	18.10	17.62	15.99	15.92	15.73	15.25	12.55
	$C_2 \times P_4$	18.70	18.54	18.30	17.98	16.14	16.05	15.95	15.40	12.89
	$C_2 \times P_5$	18.71	18.62	18.65	18.49	18.30	18.25	18.21	18.21	17.97

Moisture content	$C_1 \times P_1$	10.87	10.46	10.79	10.86	11.60	11.46	11.29	10.73	11.20
	$C_1 \times P_2$	10.65	10.20	10.30	10.75	11.49	11.35	11.21	10.58	11.16
	$C_1 \times P_3$	10.53	9.38	10.16	10.54	11.27	11.24	11.16	10.42	11.07
	$C_1 \times P_4$	9.98	9.60	9.94	10.46	10.69	10.62	10.50	10.39	10.82
	$C_1 \times P_5$	7.70	7.54	7.63	7.72	7.90	7.85	7.88	7.81	7.95
	$C_2 \times P_1$	9.37	9.46	9.52	9.80	10.74	10.39	10.31	10.42	10.50
	$C_2 \times P_2$	9.24	9.30	9.49	9.63	10.66	10.25	10.22	10.38	10.41
	$C_2 \times P_3$	9.08	9.27	9.36	9.41	10.52	10.20	10.14	10.29	10.33
	$C_2 \times P_4$	9.00	9.11	9.18	9.37	10.19	10.08	10.01	10.23	10.27
	$C_2 \times P_5$	7.66	7.65	7.74	7.79	7.82	7.72	7.71	7.65	7.69
Dehydrogenase	$C_1 \times P_1$	1.350	1.309	1.305	1.256	1.110	0.965	0.904	0.841	0.745
	$C_1 \times P_2$	1.390	1.319	1.314	1.266	1.163	0.982	0.946	0.856	0.751
	$C_1 \times P_3$	1.454	1.363	1.346	1.269	1.181	0.992	0.958	0.864	0.768
	$C_1 \times P_4$	1.472	1.394	1.365	1.284	1.201	1.100	0.963	0.872	0.801
	$C_1 \times P_5$	1.510	1.464	1.431	1.398	1.365	1.303	1.254	1.247	1.230
	$C_2 \times P_1$	1.411	1.345	1.319	1.310	1.271	1.230	1.101	0.895	0.814
	$C_2 \times P_2$	1.446	1.370	1.330	1.314	1.279	1.254	1.108	0.951	0.822
	$C_2 \times P_3$	1.466	1.379	1.352	1.345	1.310	1.265	1.114	0.952	0.849
	$C_2 \times P_4$	1.486	1.451	1.428	1.356	1.323	1.278	1.210	0.961	0.860
	$C_2 \times P_5$	1.516	1.478	1.456	1.422	1.382	1.373	1.339	1.301	1.293
Lipase	$C_1 \times P_1$	0.319	0.330	0.379	0.426	0.538	0.561	0.623	0.658	0.676
	$C_1 \times P_2$	0.318	0.329	0.365	0.419	0.526	0.553	0.612	0.644	0.675
	$C_1 \times P_3$	0.316	0.328	0.352	0.411	0.470	0.551	0.606	0.641	0.669
	$C_1 \times P_4$	0.308	0.323	0.348	0.368	0.449	0.533	0.597	0.636	0.661
	$C_1 \times P_5$	0.305	0.307	0.310	0.314	0.322	0.324	0.326	0.328	0.336
	$C_2 \times P_1$	0.317	0.327	0.350	0.355	0.441	0.478	0.539	0.556	0.588
	$C_2 \times P_2$	0.315	0.325	0.344	0.340	0.383	0.464	0.525	0.538	0.580
	$C_2 \times P_3$	0.310	0.322	0.337	0.335	0.362	0.457	0.521	0.530	0.573
	$C_2 \times P_4$	0.309	0.311	0.326	0.330	0.341	0.446	0.516	0.522	0.557
	$C_2 \times P_5$	0.302	0.306	0.308	0.311	0.313	0.318	0.320	0.321	0.325

C_1- Ambient condition; C_2- Cold condition; P_1- Gunny bag; P_2 - Cloth bag; P_3- High density polythene bag; P_4- Perdue improved crop storage bag; P_5- Vacuum packed bag

CONCLUSIONS

The degradation of groundnut seeds is an undesirable and harmful side effect of growing groundnuts. Viability is difficult to maintain while being stored in negative storage conditions. The study clearly showed that two primary factors affecting groundnut seed viability are temperature and seed moisture. Among the packaging materials and storage conditions, vacuum packaging and cold condition was the best for highest germination percentage, mobilization efficiency, seedling dry weight, dehydrogenase activity and lowest moisture content and lipase activity. Reduction in seeds quality parameters as storage period increases which leads to deterioration of seeds in groundnut.

FUTURE SCOPE

— Investigating the effect of different packaging materials and storage conditions on other crops.
— Studying the effect of different storage periods on seed quality parameters.
— Scope to study the effects of various seed treatment chemicals in groundnut under storage.

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