A-6228
[1-9]

RESEARCH ARTICLE | Indian Journal of Agricultural Research

Improved Seed Storage Technique in Groundnut (*Arachis hypogaea* L.) cv. G7 in Coastal Environment

T. Ramanadane[1], R. Gnanasekar[1], G. Hemalatha[1], A. Kamatchi[1], D. Kartic[1]

10.18805/IJARe.A-6228

ABSTRACT

Background: Non-availability of good quality seeds at the right time is a major problem faced by groundnut growers. Groundnut seeds lose their viability quickly due to several biotic and abiotic factors during storage. Seed moisture content, storage temperature and relative humidity are three major factors affecting seed storability in coastal environments. Generally, groundnut seeds are stored as pods in gunny bags. Those seeds lose their viability rapidly due to the moisture-pervious nature of the container. Vacuum storage techniques may help in protecting the seed quality from the external environment in coastal areas.

Methods: With this background, the experiment was conducted with two major objectives, to prolong the seed storability of groundnut and to reduce storage volume by using the kernel storage method in the place of pod storage. Each 20 kilograms of freshly harvested pods and 10 kilograms of kernels of Groundnut cv. G7 were treated with double spectrum fungicide (Carboxin 37.5% + Thiram 37.5%) and stored in three different containers *viz*., Gunny bag, High-Density Poly Ethylene (HDPE) bag and Super grain bag comprising a total of 12 treatments and those were tested at bimonthly intervals to assess the quality.

Result: The results shown that all the seed quality traits were differed significantly with duration of storage, storage container, method of storage and seed treatment. Irrespective of containers, untreated kernels lose their viability within a month of storage. Further, treated and untreated pods and kernels stored in gunny bags failed to fulfill the minimum germination standards (70%) after three months of storage. However, the kernels treated with fungicide and stored in HDPE or Super grain bags fulfilled minimum germination standards even after 11 months of storage. Hence, groundnut kernels treated with fungicide may be safely stored in Super grain bags or HDPE bags with reduced volume of storage as compared to pod storage. Accordingly, kernel storage in groundnut is possible if kernels pre-treated with double spectrum fungicide (Carboxin 37.5% + Thiram 37.5%) and stored in super grain bags or HDPE bags. Thus, the results have a high degree of practical utility for groundnut farmers and seed growers.

Key words: Coastal environment, Containers, Groundnut, Seed storage, Seed treatment.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), commonly known as peanut, is a self-pollinating crop belonging to the family Fabaceae. It is one of the most popular and important legumes, food and oilseed crops used for humans and livestock, which ranked 4th important oilseed crop and 14th food crop in the world. Non-availability of good quality seeds at the right time is a major problem met by the groundnut growers. In addition, they are also facing difficulties while storing seeds because seed storability affected by several biotic and abiotic factors. Being an oil seed crop, groundnut seed suffers from many pathogens as compared to starchy seeds, which lead to quick deterioration during storage. Poor post-harvest handling and storage conditions lead to the quick development of fungi in the seeds. Seed storage under coastal environments is a critical aspect of maintaining seed viability and longevity. Out of several factors affecting the seeds in storage, seed moisture, relative humidity and storage temperature are the most important (Agrawal, 1976). These two environmental factors are always high in the coastal areas and beyond the control of seed suppliers or farmers. Karaikal region, where the experiment was conducted comes under the Eleventh Agro Climatic Zone of India under Fifteen All India Agro Climatic Zonal Classification by Planning Commission of India and it is classified as PC_2 - Coastal deltaic alluvial plain zone. Karaikal has a tropical climate with a mean maximum and minimum temperature of 32.9°C and 24.2°C, respectively (Mean of 27 years; 1996 to 2023). The mean annual total rainfall is 1398.6 mm. The total annual evaporation is 1942.2 mm. The mean annual morning and evening relative humidity are 87.4% and 63.9%, respectively. Hence, storing the groundnut seeds from harvest to the next sowing season with the required vigour and viability is a huge challenge in successful seed production. Fungicide seed

[1]Seed Technology Research Unit, Department of Plant Breeding and Genetics, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal-609 606, Puducherry(UT), India.

Corresponding Author: T. Ramanadane, Seed Technology Research Unit, Department of Plant Breeding and Genetics, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal-609 606, Puducherry(UT), India.
Email: ramanadane1971@gmail.com

How to cite this article: Ramanadane, T., Gnanasekar, R., Hemalatha, G., Kamatchi, A. and Kartic, D. (2024). Improved Seed Storage Technique in Groundnut (*Arachis hypogaea* L.) cv. G7 in Coastal Environment. Indian Journal of Agricultural Research. 1-9. DOI: 10.18805/IJARe.A-6228.

Submitted: 18-03-2024 **Accepted:** 05-09-2024 **Online:** 21-11-2024

treatment has been broadly practiced as cheap insurance against seed and soil-borne pathogens in legume-producing areas (Getachew and Abeble, 2021) and played a significant role in inhibiting storage fungi and this might be attributed to minimal coat damage to peanut seeds (El-Deriny *et al*., 2018).

Groundnut pods are normally stored in gunny bags and those seeds deteriorate rapidly because of the moisture pervious nature of the container, therefore vacuum packaging may be engaged to rectify the same problem. Vacuum storage increases storability or shelf life by inhibiting the growth of microorganisms and improves hygiene by reducing the danger of cross-contamination. The Grain Pro Super bag (Introduced by Grain Pro Agro Pvt. Ltd, Israel is a multilayered polythene bag consisting of inert gas in between two layers) exploited for safe storage of seeds / dry grains of several crops. Rice seeds stored in Super grain bags maintain their viability for up to 12 months under ambient conditions (Rickman, 2004). After being dried to the optimum moisture content (≤ 9%), seeds are packed in vacuum storage to reduce the respiration of seed, infection and infestation, which minimizes the deterioration rate, whereas the seeds stored with higher-moisture content will result in mould attack, lose seed viability and death of the seed (Meena *et al*., 2017).

Groundnut kernel storage is not practiced because, when it is stored as kernels in gunny bags, the high moisture content, relative humidity and temperature in the storage atmosphere triggers insect infestation and pathogen infection results in quick deterioration of seeds. Kernels packed air-tightly and sealed in vacuum storage containers may restrict the influence of the storage environment, increase the efficacy of the seed treatment and also reduce the storage volume in groundnut seed storage. With this information, the experiment was conducted to study the effect of seed treatment and packaging material on prolonging the seed storability of groundnut and also to study the effect of the kernel storage method on reducing the storage volume in groundnut.

MATERIALS AND METHODS

Freshly harvested pods of groundnut cv. G7 were dried to below 8% kernel moisture content. Sufficient quantities of pods were decorticated and the kernels were graded with a spiral separator followed by manual grading. Each 20 kilograms of pods and 10 kilograms of kernels of groundnut cv. G7 were treated with double spectrum fungicide (Carboxin 37.5% + Thiram 37.5%) @ 2g kg^{-1} of seeds. Untreated and treated pods and kernels were stored in three different containers *viz*., Gunny bag, High Density Poly Ethylene (HDPE) and Super grain bag formed the 12 treatments and evaluated for their performance in storage (Fig 1). Seed samples were taken in each container at bimonthly intervals and tested for seed moisture content, germination, seedling length, seedling dry weight, vigour index and seed infection at Seed Technology Research Laboratory of Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA and RI), Karaikal, Puducherry (UT), India during 2021-22. Seed moisture content was measured on DICKEY-John |GAC® 500 XT digital moisture meter and expressed in percentage. The germination test was carried out with the sand method prescribed by the International Seed Testing Association (Anonymous, 2016) and observations on shoot length, root length and seedling dry weight were recorded. The seedling vigour indices I and II were computed as per the procedure prescribed by Abdul-Baki and Anderson (1973). The standard blotter method was used to determine the pathogen infection (Anonymous, 2016) of groundnut seeds. The data were statistically analysed using a Factorial Completely Randomized Design by adopting the procedure described by Panse and Sukatme (1978).

RESULTS AND DISCUSSION

Seed moisture content

Maintaining the seed in good physical and physiological condition from harvest time to the next planting season is

Fig 1: Flow chart on materials and methods used in the experiment.

the most important role of seed storage. The biological activity in the seeds had enhanced due to higher moisture content and also causes excessive heating; further promoting insect activities and mould growth. Hence, in highly humid areas like coastal environments, consideration should be given to the type of storage container which can protect the seed from atmospheric moisture (relative humidity of air) during storage. Reliable packaging materials, relative humidity (RH), temperature and seed moisture content (SMC) highly influence the seed longevity in storage (McDonald, 1999; Murdock *et al*., 2012;Bakhtavar *et al*., 2019b) but seed SMC is one of the most important factors that affect seed quality in storage (Bradford *et al*., 2018). Bewley *et al*. (2013) pointed out that high moisture content during storage as a greatest risk for seed quality. In the present study, seed being highly hygroscopic, moisture content was increased with storage period irrespective of containers used; however, significantly differed with types of containers (Table 1). The rate of increase was significantly higher in gunny bags followed by HDPE bags and Super grain bags. A gain in seed moisture content of 1.8%, 1.1% and 0.4% was observed in gunny bags, HDPE bags and Super grain bags, respectively after 11 months of storage. Seeds stored in Super grain bags recorded the least moisture content throughout the storage period as compared to HDPE bags and gunny bags; this might be due to the sensitivity of the container to absorbing moisture from the external environment. The moisture content of seeds fluctuates more in moisture-pervious containers than in moisture vapour-proof containers (Meena *et al*., 2017). Ramanadane and Rettinassababady (2008) reported that the seed deterioration rate in rice was higher at high moisture levels and storability differed with the type of storage container. Under humid environment, avoid practicing seed storage in cloth bag as equilibrium seed moisture content increases, which promotes seed deterioration (Afzal *et al*., 2019). The increase in value of the moisture content increased the breakdown of carbohydrates, lipids and proteins, because of accelerated metabolism and finally decreased the wheat quality (Ruska and Timar, 2010). Microbial activities also grow with increasing the values of moisture content and increase the losses of quality (Ruska and Timar, 2010). These results are in consistent with the findings of Akter and Hossain (2015).

Seed germination

Germination is the most important function of a seed as an indicator of its viability and worth as a seed (Akter *et al.,* 2014). Germination testing is an essential tool used to assess seed viability and to predict the field performance of a seed lot. Low germination is the very first sign of seed deterioration after storage and ultimately describes loss of seed vigour and viability (Afzal *et al*., 2017). Maintaining seed viability is not easy for every crop. Compared to cereals, oilseeds lose viability very fast; therefore, pest and disease-free and optimum storage condition is needed to retain their viability for a longer period. To create that optimum condition, seed treatment and selection of good storage containers are mandatory. In the present investigation, regardless of containers, seed germination

Table 1: Effect of type of storage, container and seed treatment on seed moisture content in Groundnut cv. G7 under ambient storage condition.

Treatments	Seed moisture content (%)							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	7.3	7.9	8.4	8.7	8.7	8.8	9.0	8.40
C_1T_2 - Treated pods in Gunny bags	7.2	8.0	8.2	8.8	8.7	8.9	9.4	8.46
C_1T_3- Untreated kernels in Gunny bags	7.3	7.9	8.2	8.7	8.6	8.9	9.0	8.37
C_1T_4- Treated kernels in Gunny bags	7.3	7.8	8.1	8.3	8.7	9.0	9.1	8.33
C_2T_1 - Untreated pods in HDPE bags	7.3	7.3	7.4	7.8	8.0	8.0	8.3	7.73
C_2T_2- Treated pods in HDPE bags	7.2	7.2	7.2	8.0	8.0	8.0	8.2	7.69
C_2T_3- Untreated kernels in HDPE bags	7.2	7.2	7.3	7.6	8.2	8.3	8.3	7.73
C_2T_4- Treated kernels in HDPE bags	7.2	7.2	7.2	7.6	8.3	8.4	8.4	7.76
C_3T_1- Untreated pods in Super grain bags	7.2	7.3	7.3	7.4	7.5	7.5	7.6	7.40
C_3T_2- Treated pods in Super grain bags	7.2	7.2	7.4	7.4	7.4	7.5	7.8	7.41
C_3T_3- Untreated kernels in Super grain bags	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.30
C_3T_4- Treated kernels in Super grain bags	7.2	7.2	7.3	7.3	7.5	7.5	7.6	7.37
Mean	7.2	7.5	7.6	7.9	8.1	8.2	8.3	7.83
	P	**C**	**T**	**P×C×T**				
SEd.	0.03	0.02	0.02	0.10				
CD (P=0.05)	0.06	0.04	0.04	0.20				

C_1 - Gunny bag; C_2 - HDPE bag; C_3 - Super grain bag; T_1- Untreated pods, T_2- Untreated kernels, T_3- Treated pods, T_4- Treated kernels; P - Period of storage; C - Storage container; T - Treatment. Figures in the parenthesis indicate arcsine value.

decreased during storage. Besides, seeds stored in gunny bags completely lost their viability at 7th month of storage (Fig 2). However, even after 11 months of storage, the seed germination as per Indian Minimum Seed Certification Standards (70%) was maintained in treated kernels stored in Super grain bag (77.3%) or in HDPE bag (73.3%) (Table 2; Fig 3). Thus, in the present study, hermetic storage maintained seed quality by lowering biochemical activities with emission of carbon dioxide with low MDA contents and high amount of total soluble sugars resulting in less damage due to natural ageing (Irfan *et al.*, 2019). Sudini *et al.* (2015) also demonstrated that hermetic triple-layer bags are superior to cloth bags in protecting groundnut quality parameters such as germinability, oil content and seed weight. Super Bag is made up of multilayers of poly-ethylene having a less permeable barrier layer to prevent exchange of moisture and air and has very low vapor transmission rate whereas cloth bag is porous and could not resist fluctuations in ambient RH during storage conditions (Afzal *et al.*, 2017). The ability of hermetic super bag to preserve germination in this study clearly supports the assumption that the implementation of dry chain concept resulted in better seed quality by restricting moisture gain (Bakhtavar *et al.*, 2019a). Some success results can be deciphered from the literature about the use of hermetic bags for preservation of seed quality (Williams *et al.*, 2014; Afzal *et al.*, 2017; Bakhtavar *et al.*, 2019a). Seeds stored in PICS bag and super grain bag retained the highest seed germination for a longer time (Khatri *et al.*, 2019) than other tested seed storage materials. The poor storability of groundnut pods or kernels stored in gunny bags might be due to the moisture-pervious nature of the container in which the seeds had direct contact with the storage atmosphere, which has high temperature and relative humidity in coastal environment. It is also evident from the weather data collected from the AFMU of PAJANCOA and RI, Karaikal that the sum of Mean temperature in °F and mean

Fig 2: Seed germination (%) in groundnut in sand method after seven months of storage under ambient condition.

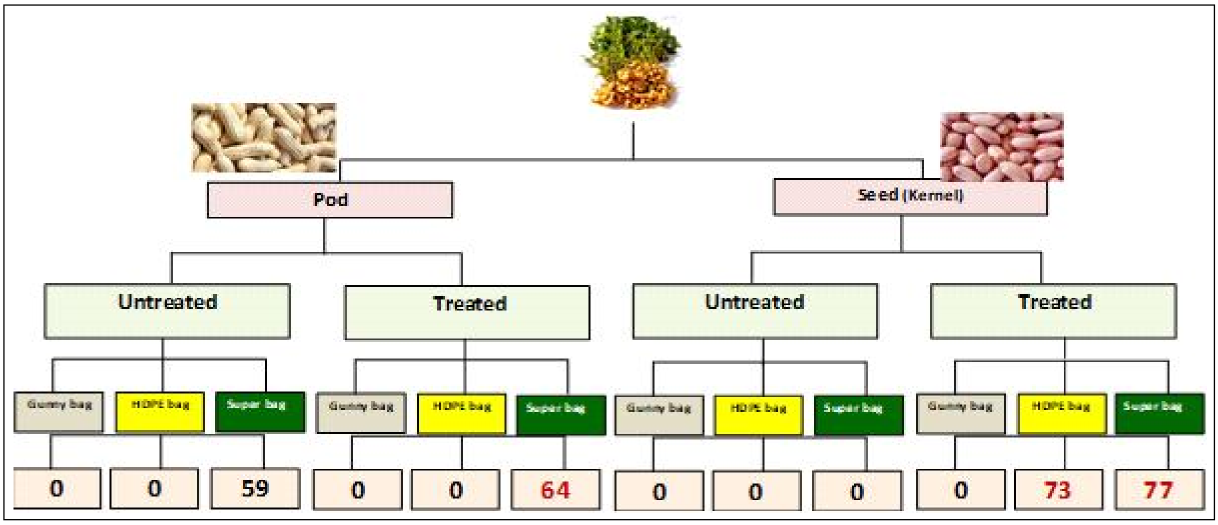

Fig 3: Seed germination (%) in groundnut after 11 months of storage under ambient condition.

Table 2: Effect of type of storage, container and seed treatment on seed germination in Groundnut cv. G7 under ambient storage condition.

Treatments	Seed germination (%)							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	96.7	96.0	92.0	6.0	0.0	0.0	0.0	41.53
	(79.6)	(79.1)	(73.6)	(14.2)	(2.9)	(2.9)	(2.9)	(36.46)
C_1T_2 - Treated pods in Gunny bags	86.7	68.7	64.0	1.3	0.0	0.0	0.0	31.53
	(68.6)	(56.0)	(53.1)	(6.5)	(2.9)	(2.9)	(2.9)	(27.56)
C_1T_3- Untreated kernels in Gunny bags	96.7	96.0	96.0	7.3	0.0	0.0	0.0	42.29
	(79 .6)	(78.4)	(78.7)	(15.6)	(2.9)	(2.9)	(2.9)	(25.91)
C_1T_4- Treated kernels in Gunny bags	99.3	96.7	96.0	13.3	0.0	0.0	0.0	43.61
	(85.3)	(80.4)	(79.5)	(21.3)	(2.9)	(2.9)	(2.9)	(39.31)
C_2T_1 - Untreated pods in HDPE bags	96.7	94.0	88.0	74.7	57.3	9.3	0.0	60.00
	(79.6)	(77.5)	(69.9)	(59.8)	(49.2)	(17.8)	(2.9)	(50.96)
C_2T_2- Treated pods in HDPE bags	86.7	67.3	63.3	61.3	46.0	0.0	0.0	46.37
	(68.6)	(55.1)	(52.7)	(51.6)	(42.7)	(2.9)	(2.9)	(39.50)
C_2T_3- Untreated kernels in HDPE bags	96.0	96.0	94.7	94.7	82.0	9.3	0.0	67.53
	(78.4)	(78.7)	(76.8)	(76.7)	(65.0)	(17.8)	(2.9)	(56.61)
C_2T_4- Treated kernels in HDPE bags	99.3	97.3	96.7	94.7	92.0	84.0	73.3	91.04
	(85.3)	(81.6)	(80.4)	(76.7)	(74.5)	(66.6)	(59.0)	(74.87)
C_3T_1- Untreated pods in Super grain bags	96.7	93.3	88.0	84.0	72.7	72.0	59.3	80.86
	(79.9)	(77.3)	(69.7)	(66.6)	(58.4)	(58.0)	(50.4)	(65.76)
C_3T_2- Treated pods in Super grain bags	86.7	68.7	64.0	60.0	59.3	3.0	0.0	48.81
	(68.7)	(56.0)	(53.1)	(50.8)	(50.4)	(10.0)	(2.9)	(41.70)
C_3T_3- Untreated kernels in Super grain bags	96.7	96.0	90.0	90.0	89.3	70.0	64.0	85.14
	(79.6)	(78.7)	(71.6)	(71.6)	(71.0)	(56.8)	(53.1)	(68.91)
C_3T_4- Treated kernels in Super grain bags	99.3	99.3	98.7	92.7	91.3	90.0	77.3	92.66
	(85.3)	(85.3)	(83.6)	(74.6)	(73.0)	(71.8)	(61.6)	(76.46)
Mean	94.8	89.1	85.9	56.7	49.2	28.1	22.8	60.94
	(78.2)	(73.7)	(70.3)	(48.7)	(41.3)	(26.1)	(20.6)	(51.27)
	P	**C**	**T**	**P×C×T**				
SEd.	0.70	0.46	0.53	2.44				
CD (P=0.05)	1.39	0.91	1.05	4.81				

Table 3: Weather parameters prevailed during Groundnut seed storage in coastal environment (High humid region) at Karaikal, India.

Month	T Max (°C)	T Min (°C)	RH I (%)	RH II (%)	Total rainfall (mm)	T Max (°F)	T Min (°F)	Mean temp. (°F)	Mean RH (%)	Sum of temp. and RH
August, 2021	36.1	25.8	80.3	53.9	79.2	96.98	78.44	87.71	67.1	154.81
September, 2021	35.5	25.2	84.3	57.6	150.2	95.9	77.36	86.63	70.95	157.58
October, 2021	33.6	25.1	89.1	70.5	378.6	92.48	77.18	84.83	79.8	164.63
November, 2021	30.3	24.0	93.2	81.3	980.8	86.54	75.2	80.87	87.25	168.12
December, 2021	30.6	22.7	92.7	69.1	56.7	87.08	72.86	79.97	80.9	160.87
January, 2022	30.5	22.3	93.1	70.1	97.7	86.9	72.14	79.52	81.6	161.12
February, 2022	30.9	21.8	91.3	66.3	20.8	87.62	71.24	79.43	78.8	158.23
March, 2022	33.1	22.9	91.0	61.3	8.9	91.58	73.22	82.4	76.15	158.55
April, 2022	34.7	25.6	89.3	62.5	10.8	94.46	78.08	86.27	75.9	162.17
May, 2022	36.5	26.2	82.3	57.3	5.5	97.7	79.16	88.43	69.8	158.23
June, 2022	37.9	26.8	69.5	45.8	2.7	100.22	80.24	90.23	57.65	147.88
July, 2022	36.4	26.6	72.5	47.3	2.25	97.52	79.88	88.7	59.9	148.60
Mean	33.84	24.58	85.7	61.9	1794.15	92.912	76.244	84.578	73.8	158.378

(Source: AMFU, PAJANCOA and RI, Karaikal).

RH in percentage was ranging between 147.88 to 168.12 (Table 3). Nevertheless, the third rule of Harrington Thump rule says that the sum of temperature in Fahrenheit and RH in percentage should not exceed 100 (Harrington, 1960). Thus, the coastal environment is unsafe for storage of seeds in moisture pervious containers like jute bags. Unprotected storage or improper storage of groundnut in jute bags can lead to reduced germination (Basave Gowda and Nanja Reddy, 2008). Begum *et al*. (2013) also reported that the high temperature and RH along with unscientific storage conditions adversely affect the seed quality. Further, untreated kernels failed to fulfill the minimum germination standards (70%) even for one month of storage probably due to high pathogenic infection as evidenced also in seed

Table 4: Effect of type of storage, container and seed treatment on seedling length (cm) in Groundnut cv. G7 under ambient storage condition.

Treatments	Seedling length (cm)							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	42.84	39.38	35.69	24.34	0	0	0	20.32
C_1T_2 - Treated pods in Gunny bags	41.21	37.01	36.27	22.94	0	0	0	19.63
C_1T_3- Untreated kernels in Gunny bags	45.44	40.16	39.30	24.39	0	0	0	21.33
C_1T_4- Treated kernels in Gunny bags	45.82	41.18	41.08	26.79	0	0	0	22.12
C_2T_1 - Untreated pods in HDPE bags	43.27	40.93	40.50	38.31	34.24	22.08	0	31.33
C_2T_2- Treated pods in HDPE bags	44.79	41.13	40.14	38.24	27.32	0	0	27.37
C_2T_3- Untreated kernels in HDPE bags	46.04	42.57	40.62	38.77	28.60	25.52	0	31.73
C_2T_4- Treated kernels in HDPE bags	47.35	44.62	42.03	40.27	38.59	32.75	22.83	38.35
C_3T_1- Untreated pods in Super grain bags	46.17	41.95	41.28	39.98	32.91	29.99	22.04	36.33
C_3T_2- Treated pods in Super grain bags	44.20	41.44	40.31	37.50	34.62	17.90	0	30.85
C_3T_3- Untreated kernels in Super grain bags	46.32	43.87	43.34	39.85	37.99	29.04	22.20	37.52
C_3T_4- Treated kernels in Super grain bags	46.22	45.40	43.44	41.61	39.89	32.15	25.61	39.19
Mean	45.0	41.6	40.3	34.4	22.9	15.8	7.7	29.67
	P	**C**	**T**	**P×C×T**				
SEd.	0.31	0.20	0.23	1.07				
CD (P=0.05)	0.61	0.40	0.46	2.11				

Table 5: Effect of type of storage, container and seed treatment on dry weight of seedlings (g/10 seedlings) in Groundnut cv. G7 under ambient storage condition.

Treatments	Dry weight of seedlings (g/10 seedlings)							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	3.37	3.33	2.96	2.85	0	0	0	1.79
C_1T_2 - Treated pods in Gunny bags	3.41	3.28	2.70	2.72	0	0	0	1.73
C_1T_3- Untreated kernels in Gunny bags	3.84	3.52	2.94	3.00	0	0	0	1.90
C_1T_4- Treated kernels in Gunny bags	3.93	3.31	3.21	3.11	0	0	0	1.94
C_2T_1 - Untreated pods in HDPE bags	3.71	3.66	3.61	3.42	3.37	3.05	0	2.97
C_2T_2- Treated pods in HDPE bags	3.62	3.37	3.10	2.81	2.74	0	0	2.23
C_2T_3- Untreated kernels in HDPE bags	4.05	3.98	3.65	3.53	3.19	3.12	0	3.07
C_2T_4- Treated kernels in HDPE bags	4.10	4.02	3.98	3.61	3.35	3.27	3.15	3.64
C_3T_1- Untreated pods in Super grain bags	3.62	3.47	3.45	3.41	3.24	3.14	3.00	3.33
C_3T_2- Treated pods in Super grain bags	3.67	3.42	3.18	2.95	2.75	2.52	0	2.64
C_3T_3- Untreated kernels in Super grain bags	4.07	4.05	3.73	3.58	3.30	3.23	3.11	3.58
C_3T_4- Treated kernels in Super grain bags	4.13	4.10	3.82	3.63	3.63	3.54	3.50	3.76
Mean	3.79	3.63	3.36	3.22	2.13	1.82	1.06	2.72
	P	**C**	**T**	**P×C×T**				1.79
SEd.	0.04	0.02	0.03	0.12				1.73
CD (P=0.05)	0.07	0.05	0.05	0.25				1.90

health tests (Table 4). El-Deriny *et al*. (2018) also opined that Vitavax treatment appeared to be safer to protect peanut seeds during storage.

Seed vigour

The seedling length has been considered as an efficient trait to identify the physiological potential differences in seed lots. Seed vigour testing is used as an indicator of the storage potential of a seed lot and in ranking various seed lots with different qualities. Generally, seeds start losing vigour before they lose their germination. Hence, vigor testingxs an important tool that is used to identify the superior quality seed. Seed ageing results in reduced seedling growth and this is a consequence of the decline in weight of mobilized seed reserves (Smayli Rana and Biradarpatil, 2018). When deterioration started in stored seeds, a

Table 6: Effect of type of storage, container and seed treatment on seedling vigour index I in Groundnut cv. G7 under ambient storage condition.

Treatments	Vigour index I							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	4142	3788	3282	146	0	0	0	1623
C_1T_2 - Treated pods in Gunny bags	3571	2538	2319	30	0	0	0	1208
C_1T_3- Untreated kernels in Gunny bags	4393	3856	3773	177	0	0	0	1743
C_1T_4- Treated kernels in Gunny bags	4551	3984	3948	354	0	0	0	1834
C_2T_1 - Untreated pods in HDPE bags	4183	3835	3568	2861	1963	206	0	2374
C_2T_2- Treated pods in HDPE bags	3883	2769	2543	2346	1256	0	0	1828
C_2T_3- Untreated kernels in HDPE bags	4419	4086	3848	3669	2345	238	0	2658
C_2T_4- Treated kernels in HDPE bags	4705	4343	4062	3813	3550	2746	1674	3556
C_3T_1- Untreated pods in Super grain bags	4464	3915	3633	3356	2391	2159	1308	3032
C_3T_2- Treated pods in Super grain bags	3831	2845	2578	2250	2054	54	0	1945
C_3T_3- Untreated kernels in Super grain bags	4477	4210	3902	3586	3394	2032	1421	3289
C_3T_4- Treated kernels in Super grain bags	4592	4509	4286	3853	3643	2892	1981	3679
Mean	4267	3723	3478	2203	1716	861	532	2397
	P	**C**	**T**	**P×C×T**				
SEd.	36	24	27	126				
CD (P=0.05)	72	47	54	248				

Table 7: Effect of type of storage, container and seed treatment on seedling vigour index II in Groundnut cv. G7 under ambient storage condition.

Treatments	Vigour index II							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	326	320	272	17	0	0	0	134
C_1T_2 - Treated pods in Gunny bags	296	225	173	4	0	0	0	100
C_1T_3- Untreated kernels in Gunny bags	372	338	282	22	0	0	0	145
C_1T_4- Treated kernels in Gunny bags	391	320	308	41	0	0	0	151
C_2T_1 - Untreated pods in HDPE bags	359	344	317	255	193	28	0	214
C_2T_2- Treated pods in HDPE bags	313	227	196	172	126	0	0	148
C_2T_3- Untreated kernels in HDPE bags	389	382	346	334	261	29	0	249
C_2T_4- Treated kernels in HDPE bags	407	391	385	341	309	275	232	334
C_3T_1- Untreated pods in Super grain bags	350	324	303	287	235	226	178	272
C_3T_2- Treated pods in Super grain bags	318	235	203	177	163	8	0	158
C_3T_3- Untreated kernels in Super grain bags	393	388	335	322	295	226	199	308
C_3T_4- Treated kernels in Super grain bags	410	407	377	336	331	318	271	350
Mean	360	325	291	192	159	93	73	213
	P	**C**	**T**	**P×C×T**				
SEd.	3.6	2.4	2.7	12.6				
CD (P=0.05)	7.2	4.7	5.4	24.9				

sequence of events began with a chain of biochemical events, predominantly membrane damage and impairment of biosynthetic reactions (Biabani *et al*., 2011) and then the resulting losses of various seed performance attributes, starting with reduced germination rate, reduction in vigor, more lipid peroxidation and finally seed death (Walters *et al.,* 2010). In the present investigation, maximum seedling length, dry weight of seedlings and vigour indices I and II were registered in treated kernels stored in super grain bags (25.61 cm; 3.50 g; 1981 and 271, respectively) followed by treated kernels stored in HDPE bags (22.83 cm; 3.15 g; 1674 and 232) and treated pods stored in super grain bag (22.20 cm; 3.11 g; 1421 and 199) after 11 months of storage and thus proved the necessity of fungicidal seed treatment as well as selection of moisture vapour proof storage containers for safe storage of groundnut seeds (Table 4-7). Similar findings were earlier reported by Akter *et al.* (2014) in soybean who reported that storage containers had a significant effect on root and shoot length; which decreased with the increase in storage period.

Seed health

Seed health is a major concern in any seed production programme next to the vigour and viability of seeds. Seed-borne fungi not only affect the germination and vigour of the seedling, it also acts as a source of inoculums for the disease development in the field. Hence, early finding of seed fungi is an essential activity to preserve high-quality seeds and to prevent pathogen distribution. In the present study, significantly lower seed infection was observed in treated kernels stored in super grain bags (43.3%) followed by treated kernels stored in HDPE bags (86.7%) as compared to 100% seed infection in other treatments after 11 months of storage (Table 8), since super grain bags and HDPE containers restrict moisture from the external environment, resulting in lower seed moisture content, leading to low respiration, metabolic activities and

Table 8: Effect of type of storage, container and seed treatment on seed infection (%) in Groundnut cv. G7 under ambient storage condition.

Treatments	Seed infection (%)							
	Period of storage (Months)							
	0	1	3	5	7	9	11	Mean
C_1T_1 - Untreated pods in Gunny bags	23.3	50.0	73.3	100	100	100	100	78.09
	(28.8)	(45.0)	(59.2)	(87.1)	(87.1)	(87.1)	(87.1)	(68.77)
C_1T_2 - Treated pods in Gunny bags	50.0	100	100	100	100	100	100	92.86
	(45.0)	(87.1)	(87.1)	(87.1)	(87.1)	(87.1)	(87.1)	(81.09)
C_1T_3- Untreated kernels in Gunny bags	20.0	26.7	33.3	100	100	100	100	68.57
	(26.6)	(30.7)	(35.2)	(87.1)	(87.1)	(87.1)	(87.1)	(62.99)
C_1T_4- Treated kernels in Gunny bags	0.0	0.0	20.0	100	100	100	100	60.00
	(2.9)	(2.9)	(26.0)	(87.1)	(87.1)	(87.1)	(87.1)	(54.31)
C_2T_1 - Untreated pods in HDPE bags	23.3	46.7	60.0	93.3	100	100	100	74.76
	(28.8)	(43.2)	(50.9)	(76.8)	(87.1)	(87.1)	(87.1)	(65.86)
C_2T_2- Treated pods in HDPE bags	50.0	86.7	93.3	100	100	100	100	90.00
	(45.0)	(71.9)	(79.2)	(87.1)	(87.1)	(87.1)	(87.1)	(77.79)
C_2T_3- Untreated kernels in HDPE bags	20.0	23.3	23.3	86.7	96.7	100	100	64.29
	(26.1)	(28.8)	(28.8)	(68.9)	(81.9)	(87.1)	(87.1)	(58.39)
C_2T_4- Treated kernels in HDPE bags	0.0	0.0	10.0	26.7	33.3	80.0	86.7	33.81
	(2.87)	(2.9)	(16.0)	(31.0)	(35.2)	(63.4)	(68.8)	(31.45)
C_3T_1- Untreated pods in Super grain bags	23.3	26.7	36.7	43.3	73.3	96.7	100	57.14
	(28.8)	(30.2)	(37.2)	(41.1)	(59.0)	(81.9)	(87.1)	(52.19)
C_3T_2- Treated pods in Super grain bags	50.0	86.7	100	100	100	100	100	90.96
	(45.0)	(68.9)	(87.1)	(87.1)	(87.1)	(87.1)	(87.1)	(78.49)
C_3T_3- Untreated kernels in Super grain bags	0.0	0.0	0.0	0.0	40.0	73.3	100	30.47
	(2.9)	(2.9)	(2.9)	(2.9)	(39.2)	(59.0)	(87.1)	(28.13)
C_3T_4- Treated kernels in Super grain bags	0.0	0.0	0.0	16.7	30.0	36.7	43.3	18.10
	(2.9)	(2.9)	(2.9)	(23.9)	(33.0)	(37.2)	(41.1)	(20.56)
Mean	21.7	37.2	45.8	72.2	81.1	90.6	94.2	63.26
	(23.8)	(34.8)	(42.7)	(63.9)	(71.5)	(78.2)	(81.8)	(56.67)
	P	**C**	**T**	**P×C×T**				
SEd.	1.10	0.72	0.83	3.81				
CD (P=0.05)	2.17	1.42	1.64	7.51				

infection. These results are in confirming with the earlier reports by El-Deriny *et al.* (2018).

CONCLUSION

Groundnut kernels treated with fungicide may be safely stored in Super grain bags or HDPE bags with reduced volume of storage as compared to pod storage. Accordingly, kernel storage in groundnut is possible if kernels are pre-treated with double spectrum fungicide and stored in super grain bags or HDPE bags. A similar study with more groundnut varieties needs to be undertaken for confirmation.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial assistance extended by the ICAR-Indian Institute of Seed Science, Mau for experimenting.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Abdul-Baki, A.A. and Anderson, J.D. (1973). Vigour determination in soybean by multiple criteria. Crop Science. 13: 630-637.

Afzal, I., Bakhtavar, M.A., Ashfaq, M., Sagheer, M. and Baributsa, D., (2017). Maintaining dryness during storage contributes to higher quality of maize seeds. Journal of Stored Products Research. 72: 49-53.

Agrawal PK (1976). Identification of suitable seed storage places in India on the basis of temperature and relative humidity conditions. Seed Research. 4: 6-11

Akter MA and I Hossain. (2015). Quality of some hybrid seeds of rice and control of seed-borne fungi in Bangladesh. Journal of Bangladesh Agriculture University. 13(2): 161-168.

Akter, M.N.H., Islam, M. and Kondoker, A. (2014). Seed quality of stored soybean (*Glycine max* L.) as influenced by storage containers and storage periods. The Agriculturists. 12: 85-95.

Anonymous (2016). International Rules for Seed Testing. Bassersdorf, Switzerland: International Seed Testing Association.

Bakhtavar, M.A., Afzal, I. and Basra, S.M.A., (2019). Moisture isotherms and quality of seeds stored in conventional packaging materials and hermetic super bag. PLOS One. https://doi.org/10.1371/journal.pone.0207569.

Bakhtavar, M.A., Afzal, I., Shahzad, S.M.A. and Wahid, A., (2019). Implementing the 'dry chain' during storage reduces losses and maintains quality of maize grain. Food Security. https://doi.org/10.1007/s12571-019-00905-2.

Basave Gowda and Nanja Reddy, Y.A. (2008). Storage of rabi or summer groundnut with desiccants to prolong seed viability and seedling vigour. Karnataka Journal of Agricultural Sciences. 21(3): 353-356.

Begum, A.J.M., Venudevan, B. and Jayanthi, M. (2013). Storage fungi in groundnut and the associate seed quality deterioration-Plant Pathology Journal. 12(3): 127-134.

Bewley, D.J., Bradford, K.J., Hillorst, H. and Nonogaki, H., (2013). Seeds physiology of development, germination and dormancy, 3rd editation Springer, New York.

Biabani, A., Boggs,L.C. M., Katozi, M. and Sabouri, H (2011). Effects of seed deterioration and inoculation with *Mesorhizobium cicerion* yield and plant performance of chickpea. Australian Journal of Crop Science. 5(1): 66-70.

Bradford, K.J., Dahal, P., Van Asbrouck, J., Kunusoth, K., Bello, P. and Thompson, J., (2018). The dry chain: reducing postharvest losses and improving food safety in humid climates. Trends in Food Science and Technology. 71: 84–93.

El-Deriny, M.E., Ali, A.A.G., Mersal, I.F. and El-Sobky, E.E.A. (2018). Effect of storage periods, packing materials and some treatments on peanut (*Arachis hypogaea* L.) Seed quality. Zagazig Journal of Agricultural Science. 45(3): 789-807.

Getachew, Z. and Abeble, L. (2021). Effect of seed treatment using Mancozeb and Ridomil fungicides on *Rhizobium* strain performance, nodulation and yield of soybean (*Glycine max* L.). Journal of Agriculture and Natural Resources. 4(2): 86-97.

Harrington, J.F. (1960). Thumb rules of drying seed. Crops and soils Publisher. 13: 16-17.

Irfan, A., Iram, J., Sania, Z., Hafeez, U.R., Shahzad, M. and Ahmad, B. (2019). Physiological and biochemical changes during hermetic storage of Moringa oleifera seeds. South African Journal of Botany. https://doi.org/10.1016/j.sajb.2019.11.011

Khatri, N., Pant, K., Bista, M. and Pandey, B. (2019). 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. Agricultural Science and Technology. 11. 10.15547/ast.2019.04.060.

McDonald, M.B. (1999). Effects of hermetic storage on cowpea bruchids. Seed deterioration, physiology, repair and assessment Seed Science and Technology. 27: 177-237.

Meena, M.K., Chetti, M.B., Nawalagatti, C.M. and Naik, M.C. (2017). Vacuum packaging technology: a novel approach for extending the storability and quality of agricultural produce. Advances in Plants and Agriculture Research. 7(1): 221-225.

Murdock, L.L., V. Margam, I. Baoua, S. Balfe, R.E.(2012). Shade Death by desiccation, effects of hermetic storage on cowpea bruchids. Journal of Stored Products and Research. 49: 166-170.

Panse, V.G. and Sukhatme, P.V. (1978). Statistical Methods for Agricultural Workers. ICAR Publication. pp 162-174.

Ramanadane, T. and Rettinassababady, C. (2008). Evaluation of different packaging materials for safe storage of paddy seeds in coastal areas. Oryza. 45(3): 202-205.

Rickman, J.F. (2004). Hermetically sealed grain storage systems. IRRI Report.

Ruska, L. and Timar, A. (2010). Storage of wheat at high moisture. Acta Agraria Debreceniensis. 1: 111-114.

Smayli Rana and Biradarpatil, N.K. (2018). Effect of storage on quality parameters of Groundnut (*Arachis hypogaea* L.) seed lots. International Journal of Current Microbiology and Applied Sciences. 7(12): 489-498.

Sudini, H., Ranga Rao, G.V., Gowda, C.L.L., Chandrika, R., Margam, V., Rathore, A. and Murdock, L.L. (2015). Purdue Improved Crop Storage (PICS) bags for safe storage of groundnuts. Journal of Stored Products Research. 64(B): 133-138.

Walters, C., D. Ballesteros, V.A. and Vertucci. (2010). Structural mechanics of seed deterioration, standing the test of time. Plant Science. 179: 565-573.

Williams, S.B., Baributsa, D. and Woloshuk, C., (2014). Assessing Purdue improved crop storage (PICS) bags to mitigate fungal growth and aflatoxin contamination. Journal of Stored Products Research 59. 190-196.