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ENHANCING SEED QUALITY AND INSECT MANAGEMENT IN WHEAT (*TRITICUM AESTIVUM* L.) THROUGH OPTIMIZATION OF STORAGE TREATMENTS WITH NATURAL AND CHEMICAL COMPOUNDS

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ABSTRACT

This research paper presents the findings of a laboratory experiment conducted at the School of Agriculture, ITM University, Sithouli Campus, Gwalior, India during the 2021-22 season. The study aimed to investigate the impact of natural and chemical compounds on seed quality parameters and the management of storage insects in wheat seeds, particularly the Sharbati C-306 variety. Seven distinct treatments, including a control group were utilized and the treated seeds were stored in three different containers: polythene bags, muslin cloth bags and bamboo storage structures, for duration of nine months. The results of the study demonstrated that seeds treated with Aluminium Phosphide exhibited the lowest insect infestation (2.87%) and electrical conductivity (18.99) after nine months, followed closely by neem extracts (6.07% and 20.69). Furthermore, AlP (Aluminium Phosphide) was highly effective in preserving seed quality parameters, including germination rate (90.27%), mean seedling length (13.66 cm), seed vigour indices (1233.38 and 26.8 for index 1 and 2, respectively), dry weight (0.297 gm), test weight (45.33 g) and various biochemical components like carbohydrates (71.22%) and gluten (11.5%). Neem extract also demonstrated considerable efficacy. Among the storage containers, polythene bags showed the lowest insect infestation (5.94%) and electrical conductivity (21.25). Furthermore, polythene containers effectively maintained seed quality parameters, with high germination rates (87.00%), mean seedling length (12.92 cm), seed vigour indices (1125.65 and 25.23), dry weight (0.297 gm), test weight (43.79 gm) and biochemical components (71.00% carbohydrates and 11.36% gluten).This study recommends fumigating wheat seeds with aluminium phosphide or treating them with neem extract before storing them in polythene containers for long-term storage under laboratory conditions. These measures were found to be the most effective for preserving seed quality and managing storage insects.

Key words : Aluminium phosphide, Fumigating, Neem extract, Biochemical, Muslin cloth.

Introduction

Wheat (*Triticum aestivum* L.) is a worldwide cereal that is farmed, consumed and traded. It ranked third among all the cereals produced. Carbohydrate (78.1%), protein (14.7%), fat (2.1%), minerals (2.1%) all have considerable levels (Pawan *et al*., 2011). Leavened, flat, and steamed breads, biscuits, cookies, cakes, breakfast cereal, pasta, noodles and couscous are all made from wheat flour (Cauvain *et al*., 2 001). The wheat crop was planted on around 30 million hectares (14% of global land) to produce an all-time high of 99.70 million tons of wheat (13.64 percent of global production) with a recorded average productivity of 3371 kg/ha. (Ministry of Agriculture and Farmers Welfare, Government of India, 2020-21).

It is very important to harvest wheat crop at right time to ensure its quality for storage as well as next cropping season. However, soon after harvest many organized factors form complex interconnections affects the quality which leads to seed deterioration. Therefore, wheat crop should be stored safe using proper pre-storage treatments along with the suitable containers to be kept safely. In well-maintained storage conditions, losses in wheat seed storage typically range from 1% to 2%. However, in countries like India, especially in inadequately managed storage facilities, these losses can escalate to as high as 20% to 50% (Jayas, 2012).

When, wheat is stored in jute bags, qualitative losses can be as significant as 6.6%. However, these losses can be reduced to 2% with proper storage management practices, such as storing wheat seeds in metal bins (Sinha and Sharma, 2004). Therefore, wheat seed storage with proper storage facilities is as good as additional production (Jha *et al*., 2015). The losses during storage depends on various internal and external factors such as its kind, motive of storage, environmental, duration, packaging methods, treatment during storage and storage of the grains *etc*. Besides, other factors cause storage losses are moisture percentage, microorganisms, pests and insects. Relative humidity and temperature are two other important factors, which cause damage of seeds during storage. Many problems like loss in germination and poor eating quality may occurs if wheat grains are not dried before storing (Gu *et al*., 2000; Ueno, 2003).

Given that storage is typically intended for shorter durations, having precise control over the storage time is of paramount importance. Prolonged storage can result in decreased germination rates, diminished seedling vigor, expedited seed aging, extended germination periods, increased electrical conductivity, susceptibility to insect infestation, and ultimately, a reduction in seed weight (Mersal *et al*., 2006). To estimate the quality of seed lot during storage it could be done by testing the traits such as germination percentage, electrical conductivity, SVI, test weight, root and shoot length *etc*. It has been reported that there is significant increase in insect infestation during the initial stage of storage to next six months (Seadh *et al*., 2015 and Ramadan, 2016).

There are numerous numbers of organic compounds, which are used in seed pre-storage treatments for prevention from insect infestation and prolonging storage duration. Neem (*Azadirachta indica* L.) is of the most important organic substance, which contains useful compounds and active ingredient in many neem-based insecticides (Mordue and Blackwell, 1993). Many researchers reported that seed oil extracted from neem possessed anti feedant quality, larvicidal properties and growth disrupting of huge number of insect and pests (Mathur, 2013). One of most beneficial derivatives of neem is that it is not environment toxic and does not have any bad impact on agro ecosystem. Das (1987) reported a remarkable outcome from the application of neem seed oil, demonstrating its magical effect. He observed a complete 100 percent control of pulse beetles (*Callosobruchus chinensis* L.), when neem seed oil was applied at a rate of 10 ml per kilogram of grain. In their study conducted by (Kumawat and Bhanwar, 2013) they observed that neem oil achieved the highest level of protection against insect infestation. They noted that grains preserved with neem oil did not show any grain injury, and there were no adverse effects observed on the seeds for up to 270 days of treatment. Perelló *et al.* (2013) reported that the seedling vigour index was not always improved after fungicide or garlic juice treatments. Such results suggest that although the infection load was reduced, this did not always lead to better seedling performance. However, this may depend to some extent on the cultivar.

Along with organic substance, many important fumigants such as Aluminium phosphide, Ethyl formate, Methyl bromide, Ethylene Di-Bromide, Hydrogen cyanide, Chloropicrin etc. Among these fumigants, Aluminium phosphide is considered as most cost-effective method for seed treatment that controls the insect infeststion. Aluminium phosphide tablets at the rate of 1.5g/m^3 with a fumigation period of 17 days would be very effective for complete control of invasions of strongly phosphine resistant *R.dominica* and hypothetically other species Ridley *et al.* (2011). Likeswise, Ramadan (2016) revealed different combination of phosphine had significant effect on insect infestation and final germination percentage.

Packaging seed in different storage containers such as resistance moisture or sealed containers for storage is useful. These containers are suitable for maintaining quality of seed at safe storage moisture level. The magnitude of safest to least safe containers are in sequence of moisture proof containers, various laminate, polyethylene, paper and at last cloth were least effective in storage. The effectiveness of other materials was directly associated with their ability to resist moisture (Agrawal, 1985). Polythene and gunny cloth bag were found to be good with maintained temperature, moisture content and germination (Chattha *et al*., 2012). In this respect, Naguib *et al.* (2011) indicated that wheat seed stored in aluminum and polyester bags showed high seed germination, seedling vigor and kept nutrient contents and stated that cloth bags showed lower viability and vigor parameters than plastic packages.

In our study, “Investigating the Optimization of Seed Storage Treatments for Ensuring Seed Quality Standards in Wheat (*Triticum aestivum* L.)", we focus on three core objectives: finding the best storage container, determining the optimal pre-storage treatment for wheat seeds, and assessing the impact of biochemical changes in seeds after treatment with organic and chemical compounds. Our research aims to enhance seed storage practices and minimize quality and yield losses in wheat production.

Materials and Methods

The present experiment was conducted during *Rabi* 2020-2021 at Crop Research Centre (CRC), and in Entomology Lab, School of Agriculture, ITM University, Sithouli Campus, Gwalior - 475 001 (M.P.), India. A wheat variety Sharbati C 306 was collected from local farmers field and its true to type was checked with proper seed certification standards after seed multiplication at research field.

The seeds were treated with organic & inorganic compounds (treatments) and different kind of containers. Seed of above stated wheat variety was harvested at physiological maturity and after shade drying next morning, it was stored in different containers in the laboratory. Each container contains 500 gm of seed and treated with natural and chemical compounds with five replications. Before storing the seed, it was validated that the moisture content of the seed was be 12-13 percent in each replicate and data were recorded after ninth month on seed quality attributes.

Estimation of Total Carbohydrate by Phenol Sulphuric acid method (Dubois *et al*., 1956). The mean of all observations recorded for each treatment were subjected to statistical analysis by Analysis of Variance method (Gomez and Gomez, 1984). The tables of results included the computation of the Standard Error of the Mean (Sem±) and the value of the Critical Difference (CD) to facilitate the comparison of means. For the data related to germination and field emergence, an angular (arcsine) transformation, as outlined by Snedecor and Cochran (1967) was applied to the values enclosed in parentheses before subjecting them to statistical analysis. The statistical calculations were prepared by two factorial Completely Randomized Design (CRD) for laboratory data. All statistical analyses were done using R package doe bioresearch (Popat and Banakara, 2020). The following parameters were estimated for each treatment from the Analysis of Variance.

Table 1 : Different treatments of organic and inorganic compounds.

Treatment	Treatment details
T_0	Control
T_1	Neem Leaf Extract
T_2	Ginger Powder
T_3	Garlic Cloves
T_4	Neem+Ginger+Garlic
T_5	Camphor
T_6	Aluminium Phosphide

Table 2 : Different treatments of containers used under study.

Containers	Treatment details
C1	Polyethene bag
C2	Muslin cloth bag
C3	Bamboo storage structure lined

Table 3 : Taking all the interactions among treatments and containers our total treatments was 21, each with 5 replications. Mentioned as follows:

Treatments	Treatments detail
C1T0	Control with Polythene bag
C1T1	Polythene bag + Neem Leaf Extract
C1T2	Polythene bag + Ginger powder
C1T3	Polythene bag + Garlic cloves
C1T4	Polythene bag + Neem Extract + Ginger powder + Garlic cloves
C1T5	Polythene bag + Camphor
C1T6	Polythene bag + Aluminum phosphide
C2T0	Control with Muslin bag
C2T1	Muslin cloth bag + Neem Leaf Extract
C2T2	Muslincloth bag + Ginger powder
C2T3	Muslin cloth bag + Garlic cloves
C2T4	Muslin cloth bag + Neem Leaf Extract + Ginger powder + Garlic cloves
C2T5	Muslinclothbag+Camphor
C2T6	Muslincloth bag + Aluminum phosphide
C3T0	Control with bamboo lined storage structure
C3T1	Bamboolined + Neem Leaf Extract
C3T2	Bamboo lined + Ginger powder
C3T3	Bamboo lined + Garlic cloves
C3T4	Bamboo lined + Neem leaf extract + Ginger powder + Garlic cloves
C3T5	Bamboo lined + Camphor
C3T6	Bamboo lined + Aluminum phosphide

Results and Discussion

Analysis of Variance after nine months of storage for seed quality

Based on Analysis of Variance of the seed quality parameters, significant variation was observed among

Table 4 : Analysis of Variance after nine months of storage for seed quality.

S. no.	Source of Variation	Container	Treatment	Container × Treatment	Error
	Degree of Freedom	**2**	**6**	**12**	**84**
	Characters	**Mean Sum of Squares**			
1	Germination percentage	142.87**	144.88**	4.14^{NS}	2.84
2	Root Length	1.50**	4.15**	0.01^{NS}	0.05
3	Shoot Length	0.83**	0.93**	0.03^{NS}	0.05
4	Seedling Length	4.55**	8.78**	0.03^{NS}	0.09
5	Seed Vigor Index-I	107800.15**	156673.30**	957.96^{NS}	1111.32
6	Dry Weight	0.001**	0.001**	0.00^{NS}	0.00
7	Seed Vigor Index-II	27.93**	34.24**	0.45^{NS}	0.29
8	Insect Infestation	103.20**	93.82**	2.72**	0.97
9	Electrical Conductivity	73.49**	65.70**	2.26^{NS}	1.52
10	Carbohydrate	8.28**	6.64**	0.55**	0.11
11	Gluten	0.18**	0.29**	0.04^{NS}	0.04
12	Test Weight	27.03**	24.22**	1.07**	0.42

**Level of significance at 1%.

the container for all the characters such as germination percentage, root length, shoot length, seedling length, seed vigour index – I, dry weight, seed vigor index –II, insect infestation, electrical conductivity, carbohydrate, gluten content and test weight (Table 4). Significant variation was observed among the treatments for all the characters like germination percentage, root length, shoot length, seedling length, seed vigour index – I, dry weight, seed vigor index –II, insect infestation, electrical conductivity, carbohydrate, gluten content and test weight. Interactions between treatments and containers were found non-significant for almost all the characters except insect infestation, carbohydrate and test weight.

Pooled analysis of variance (ANOVA) for seed quality attributes

A combined pooled ANOVA was performed to know the individual and overall interaction effect of treatment, container, duration of storage and interaction between them for all seed quality traits studied tabulated in Table 5. Significant variation was observed among the containers for almost all traits except dry weight and gluten. Significant variation was observed among the treatments for all traits. Significant variation was observed among all the three periods for all traits studied. Interactions between container and treatments were found non-significant for all the traits. It was observed that the variation present between the container and period was significant for germination percentage, seed vigor index–I, seed vigor index–II, insect infestation, electrical conductivity, carbohydrate and gluten content and other traits were non- significant like root length, shoot length, seedling length, dry weight and gluten percentage. It was observed that the variation present between the treatment and period was highly significant for all characters except gluten percentage. It was observed that the variation present between the container, treatment and period was found non-significant for all the traits.

With changing climate condition in the country put an alarming situation towards production and productivity of wheat crop. In 2021-22, slightly decline in wheat production was noticed due to unexpected early heat waves, which causes increased unfilled grains leads to production reduction. Scientific researcher has made huge contribution towards developing wheat varieties resistant to biotic and abiotic stress which added major impact on boosting high production and low-cost cultivation. In India, wheat crop is procured in summer season and hence, moisture content has to be maintained for storage. Furthermore, wheat crop has to be transported from procuring region to consuming region. Therefore, proper storage is required to maintain the quality of wheat seed for consumer (Kumar *et al*., 2021).

During procuring, the wheat seeds need pre-storage treatment for short term storage as well as long term storage for maintains the seed quality attributes. Generally, in India wheat crop is storage for one cropping season to another cropping season for either consuming purpose or using as seed for growing next wheat crop. Due to

Table 5 : Pooled analysis of variance (ANOVA) for seed quality attributes.

S. no.	Source of Variation	Periods	Container	Treatments	Container × Period	Treatment × Period	Container × Treatment	Container × Treatment × Period	Error
	Degree of Freedom	**3**	**2**	**6**	**6**	**18**	**12**	**36**	**336**
	Characters					**Mean Sum of Square**			
1	Germination%	1889.38**	155.22**	145.75**	29.41**	25.31**	3.04^{NS}	1.74^{NS}	2.42
2	Root Length	234.61**	4.01**	7.41**	0.32^{NS}	1.23**	0.05^{NS}	0.03^{NS}	0.27
3	Shoot Length	130.98**	1.15*	2.28**	0.20^{NS}	0.38*	0.07^{NS}	0.03^{NS}	0.18
4	Seedling Length	715.0971**	9.29**	17.64**	1.03^{NS}	2.84**	0.09^{NS}	0.08^{NS}	0.51
5	Seed Vigour Index-I	9445458**	182581**	254290**	22876**	41486**	1342^{NS}	848^{NS}	4501
6	Dry Weight	0.035948**	0.000632^{NS}	0.001304**	0.000295^{NS}	0.000579**	0.00027^{NS}	0.000313^{NS}	0.000285
7	Seed Vigour Index-II	909.78**	32.76**	37.95**	8.90*	11.53**	2.79^{NS}	3.03^{NS}	2.80
8	Insect Infestation	1154.00**	74.51**	84.67**	22.87**	18.10**	1.01^{NS}	0.78^{NS}	0.80
9	Electrical Conductivity	967.81**	73.56**	66.17**	14.66**	12.36**	1.02^{NS}	0.83^{NS}	1.23
10	Carbohydrate	62.27**	5.64**	10.68**	4.88*	1.60**	0.66^{NS}	0.191^{NS}	0.446
11	Gluten	1.08**	0.20^{NS}	1.19**	0.20^{NS}	0.04^{NS}	0.09^{NS}	0.03^{NS}	0.11
12	Test weight	286.21**	16.63**	21.37**	6.70**	4.63**	0.33^{NS}	0.38^{NS}	0.27

**Level of significance at 1%.

improper treatment and lack of proper seed storage, chances of seed deterioration led to loss in germination, weight, root length, shoot length, seed vigor index and other traits. Several natural and chemical materials are known to be used in storage of wheat seeds. They exhibit varied effects on insect pest infestation and seed quality during storage. In present study, we aim to identify suitable pre-storage treatments and storage container for maintaining seed quality for seed storage.

In our study, combined pooled ANOVA revealed significant decline was observed with increased period of storage for germination percentage, root length, shoot length, fresh weight, dry weight, seed vigor index, electrical conductivity, rotten grain and 1000 seed grain weight. Seed quality attributes using different treatments combination along with various packaging materials such as polythene bags and muslin cloth bag were reported by several workers (Ahmad *et al.*, 2000; Spano *et al.*, 2004; Channabasanagowda *et al.*, 2008) and biochemical activity by Rehman *et al.* (1999), Irma and Leopold (1992), Shelar (2007), Ahmad *et al.* (2000) and Tatipata (2010).

Effect of storage periods

With increment of storage periods of wheat grains at nine months significantly affected storage characters (insect infestation and weight loss percentages) seed viability and quality (final germination percentage, seedlings length, seed vigour, dry weight) of wheat as shown in mean performance tabulated in Table 8 and 9. After nine months of storage, a significant difference was noted among all the treatment groups in terms of all observed traits. The highest observations were recorded in C1T6. In general, it was observed that the interactions between various treatments and containers were not statistically significant across different time periods for most of the characteristics studied. Subsequently, when individual treatments were observed after nine months and containers were analyzed across time periods, it was found that the highest values observed in C1except insect infestation and electrical conductivity tabulated in Tables 6 and 7. Observations have revealed a noteworthy increase in insect infestation and weight loss as the storage period extended up to nine months from the beginning of storage. This trend is likely attributable to the fluctuations in temperature and humidity that occur during the storage period, which may impact the stability of the stored grains (Attia *et al.*, 2015). Regarding the final germination percentage of wheat, there was a notable and statistically significant decrease as the

Table 6 : Effect of Interaction between Containers and Duration of 9 months for germination percentage, root length, shoot length, seedling length, seed vigour index-I and II.

	Germination %	Root length	Shoot length	Seedling length	Seed Vigour Index-I	Seed Vigour Index-II
C-1	87.00[a]	7.09[a]	5.83[a]	12.92[a]	1125.65[a]	25.23[a]
C-2	86.11[b]	6.92[b]	5.73[a]	12.65[b]	1090.49[b]	24.71[b]
C-3	83.14[c]	6.68[c]	5.53[b]	12.21[c]	1016.89[c]	23.49[c]
SE (m)	**0.29**	**0.04**	**0.04**	**0.05**	**5.64**	**0.09**
CD	**1.06**	**0.14**	**0.15**	**0.19**	**21.00**	**0.34**

Table 7 : Effect of Interaction between containers and duration of 9 months for dry weight, insect infestation, electrical conductivity, carbohydrate %, gluten % and test weight.

	Dry weight	Insect Infestation	Electrical Conductivity	Carbohydrate %	Gluten %	Test weight
C-1	0.290[a]	5.94[c]	21.25[c]	71.00[a]	11.36[a]	43.79[a]
C-2	0.287[b]	7.49[b]	21.89[b]	70.43[b]	11.26[b]	43.10[b]
C-3	0.282[c]	9.37[a]	24.02[a]	70.03[c]	11.40[a]	42.05[c]
SE (m)	**0.001**	**0.17**	**0.21**	**0.06**	**0.03**	**0.11**
CD	**0.002**	**0.62**	**0.78**	**0.21**	**0.12**	**0.41**

storage period extended up to nine months. The deterioration of the seeds during storage can be attributed to damage to various components, including the membrane, enzymes, proteins, and nucleic acids. Over time, the accumulation of such degenerative changes leads to the complete disorganization of membranes and cell organelles, ultimately resulting in seed death and a loss of germination capacity (Roberts, 1972). These results are in agreement with those reported by Rathore *et al.* (2022) and Ramadan (2016).

Effect of pre-storage treatments and containers on the storage of wheat seed

It was noted that the interaction between treatments over time and containers was found to be statistically significant for most of the characteristics, with the exceptions of insect infestation and electrical conductivity, as elaborated and presented in Tables 10 and 11. Following nine months of storage, the highest observations were recorded for T_6, except for insect infestation and electrical conductivity.

Germination percentage

The germination percentage of wheat seed declined consistently with increment of storage period with in all treatment combinations which may due to ageing and depletion of food reserved and decreased in synthetic activity of seed. Furthermore, highest germination percentage was found highest for variety which is kept in polythene bag and treated with neem leaf powder and aluminum phosphide (T_6) where, polythene bag container treated with aluminum phosphide was found to be best (Rathore *et al.*, 2022). It may be due to Neem seed oil is considered as anti feedant, repellent, growth disrupting and larvicidal properties against a large number of pests (Mathur *et al.*, 2013). These results are due to maintenance of moisture content during the long-term storage period and hence resulted in decreased respiration rate, metabolic activities and maintenance of higher seed vigour during storage. Chattha *et al.* (2012) and Ramadan (2016) confirmed these results. There is enough evidence from studies conducted so far that phosphine used in insecticidal treatments under normal conditions does not affects the germination of seeds observed by Strong Matos *et al.* (2006). Regarding treatment and container similar finding were reported by Badawi *et al.* (2014), Chattha *et al.* (2012), Verma *et al.* (2003) and Raikar *et al.* (2011).

Seedling length and Seed Vigour Index

Seedling lengths were declined consistently with increasing storage period. Highest value of seedling length was recorded in (T_6) polythene container treated by aluminium phosphide followed by neem leaf powder. Similar findings were reported by Seadh *et al.* (2015). For increased germination, root shoot length, dry weight and vigour index for organic substance with different containers were reported by Karthika *et al.* (2013) and Kamdi *et al.* (2014). Vanangmudi (1988) reported that

Table 8 : Mean Performance of traits after 9 month of storage period for germination percentage, root length, shoot length, seedling length, seed vigour index-I and II.

Treatment	Germination %	Root length	Shoot length	Seedling length	Seed Vigour Index-I	Seed Vigour Index-II
C1T0	84.00	7.00	5.80	12.80	1,075.76	24.28
C1T1	89.00	7.80	6.10	13.90	1,237.28	26.65
C1T2	89.00	7.04	5.90	12.94	1,151.58	25.86
C1T3	83.00	6.50	5.55	12.05	1,000.17	23.27
C1T4	87.00	6.80	5.60	12.40	1,078.66	24.81
C1T5	86.00	6.63	5.72	12.35	1,061.92	24.44
C1T6	91.00	7.85	6.15	14.00	1,274.15	27.30
C2T0	83.00	6.88	5.75	12.63	1,048.42	23.81
C2T1	88.00	7.51	6.03	13.54	1,191.79	26.03
C2T2	88.00	6.89	5.82	12.71	1,118.85	25.33
C2T3	83.00	6.32	5.42	11.74	974.15	23.01
C2T4	85.00	6.66	5.47	12.13	1,031.04	23.94
C2T5	85.00	6.43	5.59	12.02	1,021.69	23.82
C2T6	90.80	7.74	6.00	13.74	1,247.46	27.02
C3T0	81.00	6.62	5.69	12.31	997.36	22.99
C3T1	87.00	7.42	5.82	13.24	1,151.92	25.49
C3T2	84.00	6.66	5.40	12.06	1,012.77	23.58
C3T3	79.00	6.10	5.22	11.32	893.87	21.56
C3T4	82.00	6.42	5.19	11.61	951.95	22.62
C3T5	80.00	6.20	5.45	11.65	931.85	22.11
C3T6	89.00	7.31	5.93	13.24	1,178.52	26.08
Grand Mean	**85.42**	**6.90**	**5.70**	**12.59**	**1,077.67**	**24.48**
CD	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
SE(m)	**0.75**	**0.10**	**0.10**	**0.14**	**14.91**	**0.24**
CV	**1.97**	**3.15**	**4.09**	**2.44**	**3.09**	**2.19**

seeds stored in paper aluminium foil, polyethylene laminated pouches showed greater viability and vigour compared to store in cloth bags. Container reduced the accelerated aging which normally controlled the germinability of seeds under room condition. Similar trends were seen in case of root-shoot length, fresh weight, dry weight etc. The increases in both root and shoot lengths considered as a result of vigour enhancement. Similar results were obtained for seed vigour index by Chattha *et al.* (2012) and Ramadan (2016).

Dry weight

Dry weight decreased significantly due to increased storage period and in dry weight again polythene bag along with neem leaf powder and aluminium phosphide (T_6) had found superior. This similar pattern was observed by Seadh *et al.* (2015), Chattha *et al.* (2012), Ramadan (2016) and Vanangmudi (1988). It is due to seed deterioration during storage.

Insect Infestation

During storage, wheat grains are attacked by a number of storage insect pests *viz. Tribolium castaneum* (Herbst) (rust-red floor beetle), *Sitophilus oryzae* (Lin) (rice weevil) and *Rhyzopertha dominica* (Fab) (lesser grain borer), responsible for post-harvest losses accounting for nearly Rs. 1,300 crores (IGMRI, 2019). The lowest insect infestation and highest weight of seed of wheat grains were recorded in samples of wheat grains sealed stored in (T_6) polyethylene "nylon" packages and treating wheat grain with phosphine followed by neem oil. Similar research was also observed by Badawi *et al.* (2014), Ramadan (2016), Seadh *et al.* (2015), Kumawat and Bhanwar (2013) and Tariq *et al.* (2013).

Electrical Conductivity

The estimation of Electrical Conductivity (E.C.) of stored seed was the simplest method for assessment of seed quality. Seeds of less vigor leach out higher quantity of solutes and it would show greater value of E.C. The

Table 9 : Mean Performance of traits after 9 month of storage period for dry weight, insect infestation, electrical conductivity, carbohydrate %, gluten % and test weight.

Treatment	Dry weight	Insect Infestation	Electrical Conductivity	Carbohydrate %	Gluten %	Test weight
C1T0	0.289	7.20	23.22	70.9	11.30	43.2
C1T1	0.299	4.40	20.10	71.32	11.50	44.49
C1T2	0.291	6.40	19.92	71.01	11.33	43.53
C1T3	0.280	8.40	24.00	70.9	11.26	42.58
C1T4	0.285	6.80	21.22	71.23	11.45	43.44d
C1T5	0.284	7.00	21.82	69.99	11.25	43.28
C1T6	0.300	1.40	18.46	71.63	11.45	46.04
C2T0	0.287	8.20	24.06	70.62	11.29	42.69
C2T1	0.296	6.20	20.70	71.02	11.35	43.61
C2T2	0.288	6.60	20.68	70.84	11.30	44.07
C2T3	0.277	11.20	24.02	69	10.95	41.09
C2T4	0.282	8.80	22.56	70.85	11.24	42.43
C2T5	0.280	7.80	22.62	69.46	11.22	42.86
C2T6	0.298	3.60	18.60	71.22	11.47	44.94
C3T0	0.284	11.80	25.50	70.1	11.22	40.82
C3T1	0.293	7.60	21.28	70.62	11.55	43.03
C3T2	0.281	9.80	24.24	70.44	11.40	41.94
C3T3	0.273	12.20	26.90	68.8	11.22	40.42
C3T4	0.276	9.80	24.90	70.21	11.49	41.77
C3T5	0.276	10.80	25.40	69.22	11.21	41.32
C3T6	0.293	3.60	19.90	70.81	11.71	45.01
Grand Mean	**0.286**	**7.60**	**22.39**	**70.49**	**11.34**	**42.98**
CD	**NS**	**1.64**	**NS**	**0.55**	**NS**	**1.08**
SE (m)	**0.001**	**0.44**	**0.55**	**0.15**	**0.09**	**0.29**
CV	**1.086**	**12.94**	**5.51**	**0.47**	**1.71**	**1.51**

increasing E.C. due to aging showed significant negative correlation with Vigor Index (V.I.) and germination percentage reported by Vanniarajan (2004), Thakur *et al*. (2004). Electrical conductivity study considered to be an indicator of seed deterioration.

Naguib *et al*. (2011) and Timotiwu *et al*. (2017) stated that increasing period from zero to eighteen months resulted in increased value of EC of wheat seed. During storage, seed has undergone deterioration indicated by electrolyte leakage and hence increase the value of EC in soaking water. Electrical conductivity study for seeds in different storage containers of treated population recorded lower value, which indicated beneficial effects of aluminum phosphide and neem leaf powder for maintaining better seed quality parameters than control.

Test weight

Test weight was decreased with increment of storage period. It might be due to variation of seed moisture content during storage, attack of the insects, which was feed on seed and also due to activity of microorganisms. Highest test weight was observed in was observed in (T_6) polyethylene container treated with aluminium phosphide. Sealed polyethylene is completely effective in maintaining seed moisture content and aluminium phosphide is completely efficient for prevention of insect's attack, so highest test weight was observed. Similar findings were observed by Chattah *et al.* (2012), Badawi *et al.* (2017), Mathur (2013), Badawi *et al.* (2014), Attia *et al.* (2015), Seadh *et al.* (2015) and Ramadan (2016).

Gluten and carbohydrate

A gradual decline in gluten and carbohydrate content was observed as the storage period increased from three to six to nine months. This may be due to some structural changes which inhibited proteolysis and amino acid solubility. Sanchez Mata *et al*. (2003) reported that respiration involves that high utilisation of simple sugars and hence both respiration and deterioration of biochemical substances increased. Similar findings were

Table 10: Effect of Interaction between Treatments and Duration of 9 months for germination percentage, root length, shoot length, seedling length, seed vigour index-I and II.

Treatment	Germination %	Root length	Shoot length	Seedling length	Seed Vigour Index-I	Seed Vigour Index-II
T_0	82.67^{de}	6.84^{b}	5.75^{b}	12.58^{b}	1040.51^{d}	23.69^{c}
T_1	88.00^{b}	7.58^{a}	5.99^{a}	13.56^{a}	1193.67^{b}	26.06^{a}
T_2	87.00^{b}	6.86^{b}	5.71^{b}	12.57^{b}	1094.40^{c}	24.93^{b}
T_3	81.67^{e}	6.31^{d}	5.40^{d}	11.70^{d}	956.06^{f}	22.61^{d}
T_4	84.67^{c}	6.63^{c}	5.42^{cd}	12.05^{c}	1020.55^{de}	23.79^{c}
T_5	83.67^{cd}	6.42^{d}	5.59^{bc}	12.01^{c}	1005.15^{e}	23.46^{c}
T_6	90.27^{a}	7.63^{a}	6.03^{a}	13.66^{a}	1233.38^{a}	26.80^{a}
SE (m)	**0.44**	**0.06**	**0.06**	**0.08**	**8.61**	**0.14**
CD	**1.62**	**0.21**	**0.22**	**0.30**	**32.09**	**0.52**

Table 11 : Effect of Interaction between Treatments and Duration for dry weight, electrical conductivity, carbohydrate %, gluten %, test weight and insect infestation.

Treatment	Dry weight	Electrical conductivity	Carbohydrate %	Gluten %	Test weight	Insect Infestation
T_0	0.287^{b}	24.26^{a}	70.54^{c}	11.27^{cde}	42.24^{d}	9.07^{b}
T_1	0.296^{a}	20.69^{d}	70.99^{ab}	11.47^{ab}	43.71^{b}	6.07^{d}
T_2	0.286^{b}	21.61^{c}	70.76^{bc}	11.34^{bcd}	43.18^{c}	7.60^{c}
T_3	0.277^{d}	24.97^{a}	69.57^{d}	11.14^{e}	41.36^{e}	10.60^{a}
T_4	0.281^{c}	22.89^{b}	70.76^{bc}	11.39^{bc}	42.55^{d}	8.47^{b}
T_5	0.280^{c}	23.28^{b}	69.56^{d}	11.23^{de}	42.49^{d}	8.53^{b}
T_6	0.297^{a}	18.99^{e}	71.22^{a}	11.54^{a}	45.33^{a}	2.87^{e}
SE (m)	**0.001**	**0.32**	**0.09**	**0.05**	**0.17**	**0.25**
CD	**0.004**	**1.19**	**0.32**	**0.19**	**0.62**	**0.95**

also observed by Rehman *et al.* (1999), Sisman and Ergin (2011), Naguib *et al.* (2011). All the treatment and container showed significant variation in the values of gluten protein and carbohydrate content over all the storage period as presented in mean table. Result showed that seeds in polythene container treated with aluminium phosphide and neem leaf powder has high carbohydrate and protein as compared to other treatments. This may be due to polythene-maintained air tight conditions and hence low moisture content. This indicated that property of protein chains forming loose mesh is not formed under low moisture content after treatment and these treatments also maintain stability of sugars. Similar results also reported by Naik and Chetti (2017).

Conclusion

The findings of this study underscore the suitability of polythene containers for seed storage, as they consistently outperformed muslin cloth and bamboo-lined storage structures across various storage periods. This superiority can be attributed to polythene's ability to resist moisture, thereby maintaining seeds at safe moisture levels. For short-term storage, up to six months, the use of organic compounds like neem leaf extract is a viable and eco-friendly option, with natural larvicidal properties and cost-effectiveness, while still preserving seed quality parameters. Conversely, for long-term storage, chemical fumigation using aluminum phosphide emerged as an effective method for managing seed storage insect pests and maintaining seed quality. It's worth noting that treating seeds with these compounds led to significant biochemical changes over the storage period, with increased respiration and deterioration of biochemical substances. Notably, seeds stored in polythene containers treated with aluminum phosphide and neem leaf powder exhibited higher levels of carbohydrates and proteins, likely due to the airtight conditions maintained by polythene, which slowed down respiration and preserved seed viability and vigor. These findings emphasize the importance of selecting the right storage methods and compounds for different storage durations and purposes.

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