Original Research Article:
full paper

(2022), «EUREKA: Life Sciences»
Number 6

EFFECT OF PACKAGES TYPES AND SOME TREATMENTS ON WHEAT SEED DURING STORAGE

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Abstract

This experiment was conducted at the laboratory of Seed Technology Sakha Agricultural Research Station, Kafr EL-Sheikh, Egypt, during the period between 2018 and 2019 seasons. The aim of this study was to evaluate the effect of packages types and some treatments on wheat seed during storage. The experiment was designed in factorial experiment in completely randomized design with four replicates. The samples were treated with the recommended dose of malathion, recommended rate of phosphine, the powders and extracts of each of (ficus, camphor, clove), the powder of copper nanoparticles and untreated seed as a control treatment. Treated seed were stored in different packages (Jute, Plastic and Polyethylene) for 18 months. The most important results can be summarized as follows: Increasing storage periods of wheat seed up to 18 months significantly affected storage efficacy, vitality and quality of wheat seed. The best results of storage efficacy of wheat recorded when seed stored in polyethylene packages, followed by seed stored in jute packages and lastly stored in plastic packages. Seed treated with copper nanoparticles were the best in germination percentage, electrical conductivity, acidity, protein percentage, carbohydrate percentage, relative density and 1000-seed weight. While treatment with malathion was the best in acidity, relative density, 1000- seed weight and insect infestation percentage. As for phosphine, it was the best in moisture percentage, insect infestation percentage and weight loss percentage. This study recommended that treated seed with copper nanoparticles before storage and stored it in polyethylene packages under the environmental conditions of the experiment in Sakha, Kafr EL-Sheikh, Egypt.

Keywords: wheat, storage packages, storage periods, plant extracts, chemical materials, copper nanoparticles, seed viability, seedling vigor, chemical composition, deterioration.

DOI: 10.21303/2504-5695.2022.002631

1. Introduction

Wheat (*Triticum aestivum vulgare* L.) is considered as a strategic cereal crop and the main food for the human. In Egypt, the total cultivated area of wheat reached about 1.425 million hectare and the total production exceeded 9.279 million tons with an average of 6.511 t/ha. Also, in Iraq, the total cultivated area of wheat reached about 1.655 million hectare and the total production exceeded 3.800 million tons with an average of 2.296 t/ha [1].

Grains loss in storage condition due to biotic and abiotic factors accounts for 10 % per year, out of which insects are contributing about 2.5 to 5.0 percent. Also, insects caused damage of stored grains and their products range from 5–10 % in the temperate countries to 20–30 % in the tropical zone. Stored wheat is vulnerable towards attack of insects and a possible infestation can deteriorate the quality as well as the quantity resulting in significant decrease in volume, substantial weight loss and reasonable germination damage [2]. Due to insect attack, there occurs a considerable increase in humidity and temperature which in turn supports the development of fungus and partial germination of grains [3].

Insect infestation in stored food commodities reduces quality and quantity of food available for human consumption [4]. Losses caused by these insects include: weight loss; discoloration and changes of flavor; mound formation; reduced nutritional value due to lowered protein levels and poor germination of seed due to embryo damage [5]. Potential contaminants from insects include excreta (uric acid), secretions, exuviate (cast skins) and webbing [4], as well as both living and dead insects. Live insects in grain can also cause additional problems. Respiring insects produce water, CO_2 and heat. Grain is hygroscopic and therefore adjusts its moisture content to that of the surrounding atmosphere. Higher infestations result in high moisture content of the grain and the grain also heats up in the areas of high insect activity (called hotspots).

Control of stored product insects relies heavily on the use of synthetic insecticides and fumigants led to problems such as environmental disturbances, increasing costs of application, pest resurgence, pest resistance to pesticides and lethal effects on non-target organisms, toxic residues in food grains in addition to direct toxicity to users [6]. Further, due to the problem of resistance to insecticides, there is an urgent need for safer alternatives to conventional.

Chemical insecticides particularly from natural sources are used for the protection of grain against insect infestation. Malathion and phosphine treatments could save the stored seed from the damage caused by insects, while cupper nanoparticles treatment had a positive effect of controlling seed deterioration (germination capacity and seedling vigor) [7].

In many areas of the world, locally available plant materials are widely used to protect stored product against damage by insect infestation [8].

The identified seed borne fungi diseases of wheat were antifungal activity against plant pathogenic fungi such as loose smut (*Ustilago tritici*) was determined in vivo by observing the inhibition of plant disease development. Seeds of Wheat were treated with 8 locally available indigenous plants namely. *Allium sativum* (Garlic), *Datura stramonium* (Datura), *Azadirachta indica* (Neem), *Allium cepa* var. aggregatum (Onion), *Carica papaya* (Papaya), *Zingiber officinal* (Ginger), *Parthenium hysterophorvus* (Parthenium), and *Curcuma longa* (Turmeric) may be grown by farmers with minimum cost and extracted by indigenous methods.

Different studies have shown that metal and metal oxide nanoparticles influence a plant's growth and development, crop yield, and quality [9].

Storage period have a huge influence on the quality of wheat seeds. Where, the goal of storing is to provide optimum preservation of physiological and physical characteristics of seed [10].

The packaging used in storage should help to reduce the rate of the deterioration process, keeping the initial seed moisture content stored in order to reduce respiration [11]. Seed deterioration is related to the characteristics of the packaging containers, depending on the greater or lesser ease of water vapor exchange between the seeds and the atmosphere [12].

Therefore, this investigation was established to study the effect of storage periods, packages types and treating wheat seed with natural and chemical materials on storage efficacy and seed viability and quality under the environmental conditions of Sakha, Kafr EL-Sheikh, Egypt.

2. Materials and methods

This study was carried out at the laboratory of Seed Technology Sakha Agricultural Research Station, Kafr EL-Sheikh, Egypt. Seed of wheat variety (Giza 171) was obtained from Wheat Research Department, Sakha Agricultural Research Station, ARC. The tested plants were extracted according to the procedures outlined [13] with some modification, the leaves of *Ficus nitida* and *Eucalyptus melliodora* were air dried in open-air for 10 days, followed by further drying in air oven at 45 ºC for two days until constant weight. The tested plants (Leaves of both Ficus *(Ficus nitida L.)* and Camphor *(Eucalyptus melliodora L.)* and flower buds of Clove *(Syzygium aromaticum L.)*) were dried and grinded using laboratory grinder into fine powder and 250 g of powder were extracted three times successively with ethanol solvent. The homogenous extract was allowed to stand for three days and extracts were filtered through Whatman No. 1 filter paper over Anhydride Sodium Sulphate. After that, the extracts were evaporated by rotary evaporator (temperature not accessed 50 ºC). The crude extract was then weighed and adjusted to 25 ml with the used solvent and preserved in refrigerator (4 ºC) until additional use.

Experimental treatments were arranged in factorial experiment in completely randomized design with four replicates. The first factor was three types of packages, i.e; Jute, Plastic (woven plastic bags), and Polyethylene. The second factor was ten treatments i.e,: Treating seeds with the recommended dose of malathion (8 %), recommended rate of phosphine (3 tablets/m^3), ficus powder (0.25 %) ficus extract (4575.8 ppm), camphor powder (0.28 %), camphor extract (141.9 ppm), clove powder (1.2 %), clove extract (39.93 ppm), copper nanoparticles powder (0.215 %) (obtained from Nano Tech. Laboratory), and untreated seed as a control.

Treated samples of wheat seed were taken and packaged in Jute, Plastic and Polyethylene packages and stored in open air warehouse for eighteen months.

Studied characters:

1. Germination percentage (%): Germination percentage was performed according to [14].
2. Electrical conductivity (µmhos/g seed): it was calculated according to [15].
3. Relative density (g/mm^3): relative density of one seed was calculated according to [16].
4. 1000 seed weight (g): this was carried out according to the [17] regulations.
5. Acidity: seed samples were taken at random from each plot and grounded to fine powder to pass through 2 mm mesh to determine acidity percentage according to [18].
6. Moisture percentage (%): the moisture percentage of the seed was calculated according to the International Seed Testing Association [19].
7. Insect infestation percentage (%): the infestation level was expressed as number and percentage damage seed according to formula of [20].
8. Weight loss percentage (%): after 18 months from storage, the dry mass (weight) losses caused by insect infestations were calculated as according to [21].
9. Protein percentage (%): estimated according to the improved Kjeldahl method [18].
10. Carbohydrate percentage (%): measured according to [22].
11. Statistical analysis: collected data were subjected to the statistical analysis as a usual technique of analysis of variance (ANOVA) for factorial experiment in completely randomized design as mentioned by [23] using "MSTAT-C" Computer software. The treatment means were compared by using the Least Significant Difference (L.S.D) method at 5 % and 1 % levels of probability as described by [24].

3. Results and discussion

Data Presented in **Table 1** show the effect of packages types and seed treatments on germination percentage after eighteen months from storage. Germination percentage of wheat seed not significantly affected by packaging materials as illustrated from **Table 1** after 18 months from storage, there are no-significant effects between packaging materials on wheat seed germination. These results are mainly because of maintenance of seed moisture content during the storage period which resulted in lower respiration rate, lower metabolic activity and maintenance of higher seed vigor during storage. These results are in harmony with those obtained by [25–30].

From tabulated data in **Table 1**, germination percentage significantly affected by seed treatments after eighteen months from storage. After 18 months from storage, treated seed with copper nanoparticles produced the highest mean of germination percentage (69.33 %), meanwhile the lowest percent (58.00 %) was recorded from control treatment (untreated seed). The seed deterioration during storage was due to the damage in membrane, enzyme, proteins and nucleic acid, in addition accumulation with time such degenerative changes result in complete disorganization of membranes and cell organelles and ultimately causing death of the seed and loss of germination. These results are in confirmation with [25, 29, 31–34].

Regarding to the effect of interaction between packages types and seed treatments on germination percentage after 18 months from storage was significant as presented in **Table 2**. After 18 months from storage, the highest mean of germination percentage (72.00 %) was obtained from treated seed with copper nanoparticles with polyethylene bags; meanwhile the lowest percent (55.00 %) was recorded from untreated seed with plastic bags. These results are in agreement with those reported by many authors such as [26, 29, 35, 36].

Table 1

Means of germination, electrical conductivity, relative density and 1000- seed weight after 18 months

Traits	Germination percentage (%)	Electrical conductivity (µmhos/g seed)	Relative density (g/mm^3)	1000-seed weight (g)
Packages types				
Jute	62.60	27.39	1.09	41.79
Plastic	60.60	27.66	1.09	41.50
Polyethylene	64.10	27.38	1.11	41.99
F test	NS	NS	NS	NS
LSD at 5 %	–	–	–	–
Seed treatments				
Control	58.00	28.33	1.03	41.37
Malathion	67.33	27.12	1.07	41.77
Phosphine	66.33	27.12	1.06	41.77
Ficus powder	59.00	27.33	1.08	41.57
Ficus extract	60.33	27.74	1.09	41.77
Camphor powder	59.33	27.67	1.11	41.60
Camphor extract	61.33	27.45	1.13	41.87
Clove powder	61.00	27.42	1.12	41.80
Clove extract	62.33	27.39	1.13	41.73
Copper Nano particles	69.33	27.20	1.14	42.35
F test	**	**	**	**
LSD at 5 %	0.123	0.009	0.009	0.009
LSD at 1 %	0.164	0.012	0.012	0.012
Interaction		–		
Package×treatment	**	**	**	**

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

Table 2

Means of germination and electrical conductivity of wheat seed as affected by interaction after 18 months

Treatments \ Packages types	Germination percentage (%)			Electrical conductivity (µmhos/g seed)		
	Jute	Plastic	Polyethylene	Jute	Plastic	Polyethylene
Control	58.00	55.00	61.00	28.14	28.80	28.05
Malathion	68.00	66.00	68.00	27.13	27.12	27.12
Phosphine	66.00	64.00	69.00	27.12	27.14	27.10
Ficus powder	59.00	58.00	60.00	27.10	27.80	27.10
Ficus extract	61.00	58.00	62.00	27.60	27.94	27.68
Camphor powder	60.00	58.00	60.00	27.59	27.85	27.56
Camphor extract	62.00	59.00	63.00	27.38	27.62	27.36
Clove powder	60.00	60.00	63.00	27.37	27.56	27.34
Clove extract	62.00	62.00	63.00	27.31	27.50	27.36
Copper nanoparticles	70.00	66.00	72.00	27.19	27.27	27.15
F test		**			**	
LSD at 5 %		0.017			0.016	
LSD at 1 %		0.022			0.021	

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

Electrical conductivity of wheat seed was not significant affected by packaging materials, as illustrated from **Table 1**.

With respect to the effect of seed treatments on electrical conductivity, the results in **Table 1** revealed that electrical conductivity was significantly affected by seed treatments after 18 months from storage. After 18 months from storage, untreated seed produced the highest mean of electrical conductivity (28.33 µmhos/g seed); meanwhile the lowest mean (27.12 µmhos/g seed) was recorded from treated seed with malathion and phosphine. The other botanicals also reduced the seed permeability, thus resulting lower electrical conductivity when compared to control. Thus, insecticide and botanicals makes the seed antifeedant and unpalaTable to insects and reduces the cracks and aberrations of seed coat and reduces the leaching of the electrolytes. These results are in harmony with those obtained by [28, 37–39].

The effect of interaction between bags type and seed treatments on electrical conductivity after 18 months from storage was significant as presented in **Table 2**. After 18 months from storage, the highest mean of electrical conductivity (28.80 µmhos/g seed) was obtained from untreated seed when stored in plastic bags, meanwhile the lowest mean (27.10 µmhos/g seed) was recorded from treated seed with phosphine after storage in polyethylene packages and treated seed with ficus powder when stored in jute or polyethylene bags. Similar finding were recorded by [28].

Relative density of wheat seed was not significant affected by packaging materials as illustrated from **Table 1**.

From tabulated data in **Table 1**, relative density significantly affected by seed treatments after eighteen months from storage.

After 18 months from storage, treated seed with copper nanoparticles produced the highest mean of relative density (1.14 g/mm^3), meanwhile the lowest mean (1.03 g/mm^3) was recorded from control treatment (untreated seed). Relative density indicates the degree of seed size and degree of fullness, when relative density increases, weight of seed increases and thus the seed yield increases. Similar finding were obtained by [40].

Regarding to the effect of interaction between packages and seed treatments on relative density after eighteen months from storage was significant as presented in **Table 3**. After 18 months from storage, the highest mean of relative density (1.16 g/mm^3) was obtained from treated seed with copper nanoparticles when stored in polyethylene bags, meanwhile the lowest mean (1.01 g/mm^3) was recorded from untreated seed after storage in jute packages.

1000-seed weight of wheat seed was not significant affected by packages as illustrated from **Table 1**.

From the listed data in **Table 1**, 1000- seed weight significantly affected by seed treatments after eighteen months from storage.

After 18 months from storage, treated seed with copper nanoparticles produced the highest mean of 1000- seed weight (42.35 g), meanwhile the lowest mean (41.37 g) was recorded from untreated seed. 1000-seed weight indicates the degree of seed size and degree of fullness, when 1000-seed weight increases, the seed yield increases. These results are in confirmation with [36, 40].

Regarding to the effect of interaction between bags type and seed treatments on 1000- seed weight after eighteen months from storage was significant as presented in **Table 3**. After 18 months from storage, the highest mean of 1000- seed weight (42.96 g) was obtained from treated seed with copper nanoparticles when stored in polyethylene bags, meanwhile the lowest mean (41.00 g) was recorded from untreated seed when stored in plastic bags. These results are in agreement with those reported by many authors such as [38, 36].

In view to the effect of packages types on acidity, results in **Table 4** indicated that there were not significant differences between packages for acidity. After 18 months from storage, there are no significant differences between packaging materials. These results are in harmony with those obtained by [41].

With respect to the effect of seed treatments on acidity, the results in **Table 4** revealed that acidity was significantly affected by seed treatments after 18 months from storage. After 18 months from storage, untreated seed produced the highest mean of acidity (33.07); meanwhile the lowest mean (20.63) was recorded from treated seed with copper nanoparticles. When acidity increases, seed deterioration increases due to exposure to oxidation and storage in humid conditions. These results are in confirmation with [39, 41].

Table 3

Means of relative density and 1000-seed weight as affected by interaction after 18 months

Treatments \ Packages types	Relative density (g/mm³)			1000-seed weight (g)		
	Jute	Plastic	Polyethylene	Jute	Plastic	Polyethylene
Control	1.01	1.04	1.04	41.50	41.00	41.60
Malathion	1.06	1.07	1.08	41.80	41.60	41.90
Phosphine	1.05	1.07	1.07	41.90	41.50	41.90
Ficus powder	1.07	1.06	1.10	41.60	41.30	41.80
Ficus extract	1.10	1.07	1.11	41.80	41.60	41.90
Camphor powder	1.11	1.11	1.12	41.60	41.40	41.80
Camphor extract	1.13	1.12	1.14	41.90	41.80	41.90
Clove powder	1.12	1.11	1.13	41.80	41.70	41.90
Clove extract	1.13	1.12	1.14	41.90	41.10	42.20
Copper Nano particles	1.14	1.13	1.16	42.10	41.99	42.96
F test		**			**	
LSD at 5 %		0.016			0.016	
LSD at 1 %		0.021			0.021	

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

Table 4

Means of acidity, moisture, insect infestation, weight loss, protein percentage and carbohydrate after 18 months

Traits	Acidity	Moisture (%)	Insect infestation (%)	Weight loss (%)	Protein (%)	Carbohydrate (%)
Packages types						
Jute	25.10	13.42	11.23	4.90	12.79	68.83
Plastic	27.08	14.36	11.79	5.07	12.81	68.55
Polyethylene	24.27	13.14	10.66	4.72	12.78	69.11
F test	NS	NS	NS	NS	NS	NS
LSD at 5 %	–	–	–	–	–	–
Seed treatments						
Control	33.07	13.67	13.73	8.03	12.92	68.23
Malathion	22.37	13.73	7.07	3.27	12.83	68.70
Phosphine	22.17	13.80	7.57	3.07	12.82	68.70
Ficus powder	26.67	13.60	12.83	5.57	12.81	68.50
Ficus extract	26.43	13.67	12.60	5.47	12.79	68.70
Camphor powder	26.33	13.53	12.90	5.40	12.79	68.67
Camphor extract	25.97	13.63	12.63	5.00	12.77	69.10
Clove powder	26.07	13.50	12.47	4.87	12.77	68.87
Clove extract	25.13	13.67	12.27	4.47	12.74	69.03
Copper Nano particles	20.63	13.60	8.20	3.83	12.72	69.80
F test	**	**	**	**	**	**
LSD at 5 %	0.169	0.009	0.115	0.518	0.029	0.009
LSD at 1 %	0.225	0.012	0.153	0.689	0.039	0.012
Interaction			–			
Package×treatment	**	**	**	**	**	**

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

Regarding to the effect of interaction between packages types and seed treatments on acidity after eighteen months from storage was significant as presented in **Table 5**. After 18 months from storage, the highest mean of acidity (32.40) was obtained from control treatment (untreated seed) after storage in jute packages or plastic packages , meanwhile the lowest mean (19.90) was recorded from treated seed with copper nanoparticles with polyethylene bags. These results are in agreement with those reported by many authors such as [35, 40, 41].

The results indicated that moisture percentage of wheat seed was not significant affected by bags type as illustrated from **Table 4**. The moisture content of seeds in packaging materials increased in long storage due to the effect of seed respiration and heat accumulation in a package.

Table 5

Means of acidity and moisture as affected by interaction after 18 months

Treatments \ Packages types	Acidity			Moisture (%)		
	Jute	Plastic	Polyethylene	Jute	Plastic	Polyethylene
Control	32.40	32.40	31.20	13.50	14.30	13.20
Malathion	22.60	22.60	21.40	13.50	14.40	13.30
Phosphine	22.10	22.10	20.90	13.60	14.50	13.30
Ficus powder	26.00	26.00	25.60	13.30	14.40	13.10
Ficus extract	26.00	26.00	25.30	13.50	14.20	13.30
Camphor powder	25.80	25.80	25.20	13.20	14.30	13.10
Camphor extract	25.40	25.40	24.80	13.40	14.50	13.00
Clove powder	25.60	25.60	24.60	13.30	14.20	13.00
Clove extract	24.50	24.50	23.80	13.50	14.40	13.10
Copper Nano particles	20.60	20.60	19.90	13.40	14.40	13.00
F test		**			**	
LSD at 5 %		0.293			0.020	
LSD at 1 %		0.390			0.027	

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

Data presented in **Table 4**, illustrated that moisture percentage significantly affected by seed treatments, after eighteen months from storage. After 18 months from storage, treated seed with phosphine produced the highest mean of moisture percentage (13.80 %), meanwhile the lowest percent (13.50 %) was recorded from clove powder. The moisture content of seeds in packaging materials increased in long storage due to the effect of seed respiration and heat accumulation in a package. Similar finding were recorded by [37, 38, 40, 42, 43].

The effect of interaction between packaging materials and seed treatments on moisture percentage after 18 months from storage was significant as presented in **Table 5**. After 18 months from storage, the highest mean of moisture percentage (14.50 %) was obtained from treated seed with phosphine and treated seed with camphor extract when stored in plastic bags, meanwhile the lowest percent (13.00 %) was recorded from treated seed with camphor extract, clove powder and copper nanoparticles when stored in polyethylene bags. The moisture content of seeds in packaging materials increased in long storage due to the effect of seed respiration and heat accumulation in a package. These results are in harmony with these obtained by [30, 44].

Regarding the effect of packages types, results in **Table 4** showed that there were no significant differences between bags type in insect infestation percentage after 18 months from storage. The results in **Table 4** clearly indicated that seed treatments had significant effect on insect infestation percentage after 18 months from storage. After 18 months from storage, untreated seed produced the highest mean of insect infestation percentage (13.73 %); meanwhile the lowest percent (7.07 %) was recorded from treated seed with malathion. Phosphine fumigations maintained a lethal concentration until the most resistant stages mature into less resistant forms. In this regard, phosphine was the primary fumigants currently being used commercially for stored products. Also, wheat seed might be infested by storage pests (insects and fungi) or might refer to the increase of consumption of some organic compounds in respiration process with increasing storage periods. These results are in confirmation with [25, 29, 45–48].

Regarding to the effect of interaction between packages and seed treatments on insect infestation percentage after eighteen months from storage was significant as presented in **Table 6**. After 18 months from storage, the highest mean of insect infestation percentage (14.80 %) was obtained from control treatment (untreated seed) with plastic bags, meanwhile the lowest percent (6.90 %)

was recorded from treated seed with malathion with polyethylene packages. These results are in agreement with those reported by many authors such as [26, 29, 44, 49].

The results showed that weight loss percentage of wheat seed not significantly affected by packages after 18 months from storage as illustrated from **Table 4**.

With respect to the effect of seed treatments on weight loss percentage, the results in **Table 4** revealed that weight loss percentage was significantly affected by seed treatments after eighteen months from storage. After 18 months from storage, control treatment (untreated seed) produced the highest mean of weight loss percentage (8.03 %), meanwhile the lowest percent (3.07 %) was recorded from treated seed with phosphine. Phosphine fumigations maintained a lethal concentration until the most resistant stages mature into less resistant forms. In this regard, phosphine was the primary fumigants currently being used commercially for stored products. Also, wheat seed might be infested by storage pests (insects and fungi) or might refer to the increase of consumption of some organic compounds in respiration process with increasing storage periods which leads to increasing dry weight loss of seed. These results are in agreement with those reported by many authors such as [25, 29, 46, 47, 50, 51].

Regarding to the effect of interaction between packages types and seed treatments on weight loss percentage 18 months from storage was significant as presented in **Table 6**. After 18 months from storage, the highest mean of weight loss percentage (8.20 %) was obtained from control treatment (untreated seed) with plastic packages, meanwhile the lowest percent (2.80 %) was recorded from treated seed with phosphine with polyethylene packages. Similar finding were recorded by [26].

In view to the effect of packages on protein percentage, results in **Table 4** indicated that there were no significant differences between packages for protein percentage. These results are in harmony with those obtained by [52].

With respect to the effect of seed treatments on protein percentage, the results in **Table 4** revealed that protein percentage was significantly affected by seed treatments after eighteen months from storage. After 18 months from storage, control treatment (untreated seed) produced the highest mean of protein percentage (12.92 %); meanwhile the lowest percent (12.72 %) was recorded from treated seed with copper nanoparticles. The protein percentages do not change during storage. However, some researchers have found a slight increase in protein percentage constantly stored. This is due to the lack of carbohydrate percentage as a result of respiration process. These results are in confirmation with [40, 44, 46, 53, 54].

Table 6

Means of insect infestation and weight loss as affected by interaction after 18 months

Packages types / Treatments	Insect infestation (%)			Weight loss (%)		
	Jute	**Plastic**	**Polyethylene**	**Jute**	**Plastic**	**Polyethylene**
Control	13.60	14.80	12.80	8.00	8.20	7.90
Malathion	7.00	7.30	6.90	3.00	3.60	3.20
Phosphine	7.50	7.90	7.30	3.20	3.20	2.80
Ficus powder	12.90	13.30	12.30	5.60	5.70	5.40
Ficus extract	12.60	13.20	12.00	5.60	5.70	5.10
Camphor powder	12.90	13.50	12.30	5.40	5.60	5.20
Camphor extract	12.70	13.10	12.10	5.00	5.20	4.80
Clove powder	12.50	13.10	11.80	4.90	5.00	4.70
Clove extract	12.40	12.80	11.60	4.50	4.50	4.40
Copper nanoparticles	8.20	8.90	7.50	3.80	4.00	3.70
F test		**			**	
LSD at 5 %		0.201			0.020	
LSD at 1 %		0.267			0.027	

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

Regarding to the effect of interaction between packages and seed treatments on protein percentage was significant after eighteen months as presented in **Table 7** after 18 months from storage, the highest mean of protein percentage (12.95 %) was obtained from untreated seed when stored in plastic bags , meanwhile the lowest percent (12.71 %) was recorded from treated seed with copper nanoparticles when stored in polyethylene bags .These results are in agreement with those reported by many authors such as [38, 44].

Carbohydrate percentage of wheat seed was not significant affected by bags type as illustrated from **Table 4**.

The data in **Table 4** revealed that carbohydrate percentage was significantly affected by seed treatments after eighteen months from storage. After 18 months from storage, treated seed with copper nanoparticles produced the highest mean of carbohydrate percentage (69.80 %), meanwhile the lowest percent (68.23 %) was recorded from untreated seed. The carbohydrate percentage decreases as a result of respiration process. These results are in agreement with those reported by many authors such as [46, 53].

Regarding to the effect of interaction between packaging materials and seed treatments on carbohydrate percentage after eighteen months from storage was significant as presented in **Table 7** after 18 months from storage, the highest mean of carbohydrate percentage (70.30 %) was obtained from treated seed with copper nanoparticles when stored in polyethylene bags, meanwhile the lowest percent (68.00 %) was recorded from control treatment (untreated seed) when stored in plastic bags. These results are in agreement with those reported by many authors such as [38].

Table 7

Means of protein and carbohydrate as affected by interaction after 18 months

Treatments \ Packages types	Protein (%)			Carbohydrate (%)		
	Jute	**Plastic**	**Polyethylene**	**Jute**	**Plastic**	**Polyethylene**
Control	12.92	12.95	12.90	68.20	68.00	68.50
Malathion	12.83	12.85	12.81	68.80	68.40	68.90
Phosphine	12.81	12.84	12.80	68.80	68.50	68.80
Ficus powder	12.81	12.82	12.80	68.50	68.30	68.70
Ficus extract	12.80	12.80	12.78	68.70	68.50	68.90
Camphor powder	12.78	12.80	12.78	68.60	68.50	68.90
Camphor extract	12.77	12.79	12.75	68.90	68.50	69.90
Clove powder	12.76	12.78	12.76	68.80	68.80	69.00
Clove extract	12.74	12.75	12.74	69.00	68.90	69.20
Copper Nano particles	12.72	12.74	12.71	70.00	69.10	70.30
F test		**			**	
LSD at 5 %		0.020			0.020	
LSD at 1 %		0.027			0.027	

*Note: Ns – non-significant; * – significant at 0.05;** – highly significant at 0.01.*

4. Conclusions

The study recommends treating wheat seed (Giza 171) before storage with copper nanoparticles powder as an alternative way of use chemicals insecticides (malathion or fumigation with phosphine) and storing in polyethylene packages to increase storage efficacy, prevent insect infestation, preserve the vitality and quality of wheat seed, reduce environmental pollution and preservation of human health.

Conflict of interest

The authors declare that they have no conflict of interest.

Financing

The study was performed without financial support.

Data availability

Manuscript has no associated data.

Acknowledgements

The authors wish to express their most sincere and gratitude to Prof. Dr. Mahmoud Ibrahim El-Emery Head Researcher at seed technology research department, Field Crop Research Institute, Agricultural Research Center, Prof. Dr. Ibrahim Fathy Mersal Head Researcher at seed technology research department, Field Crop Research Institute, Agricultural Research Center and Prof. Dr. Abd Rabou Abd El-Aziz El-Hag, Head Researcher at wheat research department, Field Crop Research Institute, Agricultural Research Center, for guidance and their great help and advices throughout this work.

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Received date 17.10.2022
Accepted date 18.11.2022
Published date 30.11.2022

How to cite: *El-Seidy, E.-S., Rashwan, E. E.-D., Selim, A., Hammad, E. (2022). Effect of packages types and some treatments on wheat seed during storage. EUREKA: Life Sciences, 6, 13–24, doi: http://doi.org/10.21303/2504-5695.2022.002631*