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Effect of storage treatments on wheat storage

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Abstract

An experiment was conducted in Laboratory for Seed Testing of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt, from 30th May, 2015 to 11th March, 2016 to study the effect of storage periods, packages types and treating wheat grains with natural and chemical materials on storage efficacy seed viability and quality under the environmental conditions of Dakahlia Governorate, Egypt. The experiment was arranged in A Factorial Experiment in Randomized Complete Block Design (RCBD) with four replications. The first factor contained three storage periods (3, 6 and 9 months). The second factor included four types of packages *i.e* normal storage (stored wheat grains in normal "twisting plastic" and gunny packages) and sealing storage (stored wheat grains in polyethylene "nylon" and metal containers). The third factor included five treatment of treating wheat grains with natural and chemical materials at the beginning of storage *i.e* control treatment (untreated grains), and treating wheat grains with thyme oil at the rate of 15%, neem oil at the rate of 20%, ascorbic acid at the rate of 500 ppm and phosphine at the rate of 8 ppm. The main results of this study could be summarized as follows: Increasing storage periods of wheat seed up to 9 months significantly affected storage efficacy and seed viability and quality. Sealing storage wheat grains in polyethylene "nylon" recorded the most excellent results of storage efficacy, seed viability and quality, followed by sealed stored in metal packages, then gunny packages and lastly in normal "twisting plastic". The best results of storage efficacy, seed viability and quality were recorded with treating wheat grains with phosphine at the rate of 8 ppm, followed by treating with neem oil at the rate of 20%, then treating with thyme oil at the rate of 15%, treating with ascorbic acid at the rate of 500 ppm and lastly control treatment (untreated grains). For enhancing storage efficacy, seed viability and quality, it could recommended that treating wheat grains with phosphine (as a chemical material) at the rate of 8 ppm or neem oil at the rate of 20% (as a natural material) before storage in polyethylene or metal packages under the environmental conditions of the experiment in Mansoura, Dakahlia Governorate, Egypt.

Keywords: Wheat, storage periods, storage packages, natural and chemical materials, phosphine, neem oil, storage efficacy, seed viability and quality.

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 (**FAO, 2017**).

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 per cent. 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 (**Phillips and Throne, 2010**). 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 (**Padin *et al.*, 2013**).

Seed deterioration during storage period 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 (**Roberts, 1972).** Moreover, prolonging storage period with high seed moisture percentage significantly caused high reduction in storage efficiency (infested seeds, damage grains percentage, grains weight loss percentage), germination characters, seed viability and quality, accelerate seed aging **(Mersal *et al*,. 2006, Rao *et al*,. 2006, Rocha-Junior and Usberti 2007, Mrda *et al*,. 2010, Naguib *et al.* (2011 and Attia *et al.*, 2014). Raza *et al.* (2010)** revealed that storage duration of 12 months generally increased moisture and fat acidity, while decreased test weight and flour yield. **Seadh *et al.*, 2015 and Ramadan, 2016)** reported that the numbers of insect infestation and yellow grains of milled rice significantly increased due to increasing storage periods from 2 to 4 and 6 months from beginning of storage.

Neem (*Azadirachta indica* L.) is a tree, which has many useful compounds, including azadirachtin and tetranotriterpenoid limonoid, the active ingredient in many neem-based insecticides (**Mordue and Blackwell, 1993**). All parts of neem especially seed oil possessed antifeedant, repellant, growth disrupting and larvicidal properties against a large number of pests (**Mathur, 2013**). Moreover, neem derivatives are generally not hazardous to agro-ecosystem, as well as insect resistance is not developed like synthetic insecticides. **Das (1987)** indicated that neem seed oil showed 100% control of pulse beetles (*Callosobruchus chinensis* L.) applied at 10 ml/kg grain. **Khan *et al.* (2013)** showed a positive potential of plant extracts as suitable substitute of conventional synthetic insecticides for the management of insect pest attacking stored commodities. **Kumawat and Bhanwar (2013)** found that the maximum fortification of insects was attained by neem oil, where no grain injury was recorded by neem oil preserved grains and no adversative effect of plant oils was observed on seed practicality for up to 270 days of treatment. **Tariq *et al.* (2013)** concluded that the insect growth inhibition was increased by increasing the dose of neem seed powder from 0.5 % to 1.0 % and 2.0 % (w/w).

The important fumigants are Methyl bromide, Ethylene Di-Bromide, Aluminium phosphide, Ethyl formate, Hydrogen cyanide, Chloropicrin etc. Phosphine fumigation offers a cost-effective method of treating grain so that insects are controlled. In this regard, **Andrew et al. (2011)** demonstrated that silo bags can be fumigated with phosphine for complete control of infestations of strongly phosphine resistant *R. dominica* and potentially other species. **Lorini *et al.* (2011)** concluded that the release of gas in phosphine starts soon after the availability of the tablets on the atmosphere, increasing the concentration over time until complete termination of the tablet steaming. **Ridley *et al.* (2011)** demonstrated that silo bags can be fumigated with phosphine (Aluminums phosphide tablets at the rate of 1.5 g/m^3 with a fumigation period of 17 days) for complete control of invasions of strongly phosphine resistant *R. dominica* and hypothetically other species. **Song *et al.* (2011)** showed that the 50% lethal concentration (LC_{50}) of phosphine to these *R. dominica* populations ranged from 0.017 to 4.272 mg/L. Of the 16 populations, 5 were of low resistance, 6 were moderately resistant, and 5 were high resistant. **Attia *et al.*, 2014 and Ramadan, 2016)** reported that treating wheat grains with some chemical insecticides treatment *i.e.* phosphine at the rates of 5, 7 and 9 ppm had a significant effect on storage efficacy traits (number of infected wheat grains, damage grains percentage and grains weight loss percentage) and final germination percentage as compared with both control treatments. **Badawi *et al.* (2014)** suggested that seed of wheat can be stored in the open air, while maintaining the seed of good quality in the moisture content does not exceed 14% after fumigation with phosphine in relative humidity up to 57%. **Attia et al. (2015) showed** that the best results of storage efficacy (number of insects, insect infestation percentage and grains weight loss percentage) of paddy rice were obtained when treating with phosphine at the rate of 6 balls/ton, followed treating with phosphine at the rate of 4 balls/ton, then phosphine at the rate of 2 balls/ton. **Seadh et al. (2015)** pointed out that the best results of physical characters of milled rice obtained when treating with phosphine at the rate of 6 balls/ton, followed treating with phosphine at the rate of 4 balls/ton, then treating with phosphine at the rate of 2 balls/ton. **Ramadan (2016)** revealed that fumigation wheat grains before beginning of storage with phosphine at the rates of 3, 5 and 7 Tablet phosphine/m3 had a significant effect on storage efficacy characters (insect infestation and weight loss percentages) and final germination percentage.

Packaging seed in moisture-resistance or hermetically sealed containers for storage was useful. The purpose of such containers was to maintain seed at safe storage moisture level. Ordinary paper and cloth containers were least effective in storage. While, various laminate and polyethylene materials were moderately effective in storage. Metal cans were completely effective in maintaining seed moisture at the initial 5% level. Such completely moisture-proof containers hermetically seal the seed and were effective for long-term storage up to 10 years or more. The effectiveness of other materials was directly associated with their ability to resist moisture **(Agrawal, 1985)**. In this respect, **Raza *et al.* (2010)** showed that moisture content was increased during storage when stored wheat grains in cotton bags and earthen pots resulting in higher test weights and flour yield. Tin containers performed better in retaining low fat acidity values. **Naguib *et al.* (2011)** indicated that wheat seed stored in aluminum and polyester bags showed high seed germination, seedling vigor and kept nutrient contents. **Chattha *et al.* (2012)** concluded that wheat seed stored in gunny; cloth and plastic bags were in good terms with temperature, moisture content and germination capacity in comparison with those in metal and earthen bins. **Chattah *et al.* (2014)** stated that stored wheat grain in metal and earthen bins was good in terms of 1000-grain weight, protein, starch and low insect-pest infestation in comparison with those in gunny, cloth and plastic bags. **Seadh *et al.* (2015)** found that the best results of physical characters of milled rice resulted from samples of milled rice grains stored in gunny packages, followed stored in normal packages (twisting plastic), and then stored in light cloth packages. **Ramadan (2016)** showed that normal storage (stored wheat grains in jute bags) and sealing storage (stored wheat grains in plastic jars and in metal packages) significantly affected storage efficacy characters (insect infestation and weight loss percentages) and final germination percentage.

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

Materials and Methods

A laboratory experiment was carried out under the laboratory conditions of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt, from 30th May, 2015 to 11th March, 2016. The purpose of the experiment was to find out the effect of storage treatments *i.e.* storage periods, packages types and treating wheat grains with natural and chemical materials on storage efficacy seed viability and quality under the environmental conditions of Dakahlia Governorate, Egypt.

The experiment was arranged in A Factorial Experiment in Randomized Complete Block Design (RCBD) with four replications. The first factor contained different storage periods of wheat *i.e.* 3, 6 and 9 months after harvesting time. The second factor included four types of packages *i.e* normal storage (stored wheat grains in normal "twisting plastic" and gunny packages) and sealing storage (stored wheat grains in polyethylene "nylon" and metal containers). The third factor included five treatment of treating wheat grains with natural and chemical materials at the beginning of storage *i.e* control treatment (untreated grains), thyme oil at the rate of 15%, neem oil at the rate of 20%, ascorbic acid at the rate of 500 ppm and phosphine at the rate of 8 ppm.

In all studied treatments, about 2.5 kg of wheat grains with 12-13% moisture content in each replicate were stored in various packages and then treated with natural and chemical materials before beginning the storage as formerly mentioned.

The studied wheat Sids 12 cultivar was obtained directly after harvesting from the Agricultural Research Station in Mansoura, Dakahlia Governorate, Agricultural Research Center, Egypt.

The plant oils under study (thyme and neem) were produced by T. Stanes & Company Limited, India and obtained from Gaara Establishment for Import and Export Co. The studied plant oils (thyme and neem) were dissolved with acetone firstly, and then diluted with water to the studied rate of each plant oil. Wheat grains were sprayed and well mixed with plant oils, and then beginning storage.

Ascorbic-Acid is produced by El-Nasr Pharmaceutical Chemicals Co., Egypt, and obtained from El-Gomhouria Company for Trading Pharmaceutical Chemical & Medical.

The phosphine (aluminium phosphide) was produced by T. Stanes & Company Limited, India and obtained from Gaara Establishment for Import and Export Co. Phosphine or hydrogen phosphide (PH_3) is very toxic to all forms of animal life, hence exposure of human beings even to small amounts should be avoided.

Studied characters:

A- Storage efficacy characters:

1- Insect infestation percentage: After each storage period (3, 6 and 9 months from harvesting), 100 grains from each treatment were manually picked from each package from different depth randomly for inspection. Grains which having holes or infestation were collected, also the grains which showed signs of insect damage were considered as infested. The infestation level was expressed as number then, percentage damage grains was estimated according to the formula described by, **Jood *et al.* (1996)**.

$$\text{Insect infestation (\%)} = \frac{\text{Number of insect damage}}{\text{Number of total grains inspected}} \times 100$$

2- Weight loss percentage: After 3, 6 and 9 months, the dry mass (weight) losses caused by insect infestation were calculated as follows according to **Dick (1987)**.

$$\text{Dry mass (weight) loss \%} = \frac{(U\,Nd) - (D\,Nu)}{U\,(Nd + Nu)} \times 100$$

Where: U = Weight of undamaged grains.
Nu = Number of undamaged grains.
D = Weight of damage grains.
Nd = Number of damaged grains.

B- Viability and vigor tests:

Random sample of 100 grains for each treatment were allowed to germinate under the environmental conditions of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt at the end of each storage period as the rules of International Seed Testing Association (**ISTA, 1996**) on top filter paper in sterilized Petri-dishes (14 cm diameter) and each Petri-dish contains 25 seeds.

The germinated grains were counted and the first count defined as the number of germinated grains at the fourth day. At the end of germination test (after 8 days of beginning germination test), the number of germinated grains were counted. Grains were categorized at the end of germination test as germinated (radical 2 mm long), nonviable (abnormal, dead or rotten grains) or hard (no imbibitions or swelling) as described by **ISTA (1996**), and the following parameters were recorded:

1- Final germination percentage (FG %): Normal seedlings of each replicate were counted after 8 days from planting and expressed as percentage according to the following equation described by **ISTA (1996)**:

$$\text{FG \%} = \frac{\text{Number of normal seedlings}}{\text{Number of total grains}} \times 100$$

2- Abnormal seedlings percentage (%): It was counted and expressed by the percentage of abnormal seedlings after 8 days according to **ISTA (1996)**.

3- Rotten grains percentage (%): It was counted and expressed by the percentage of rotten grains after 8 days according to **ISTA (1996)**.

4- Sold grains percentage (%): It was counted and expressed by the percentage of hard grains after 8 days according to **ISTA (1996)**.

Data were subjected to the statistical analysis according to the technique of analysis of variance (ANOVA) for Factorial Experiment in Randomized Complete Block Design (RCBD) as published by **Gomez and Gomez (1984)** by using "MSTAT-C" computer software package. Least significant difference (LSD) method was used to test the differences between treatment means at 5 % level of probability as described by **Snedecor and Cochran (1980)**.

Results and Discussion

1- Effect of storage periods:

Increasing storage periods of wheat grains from 3 to 6 and 9 months significantly affected storage efficacy characters (insect infestation and weight loss percentages) seed viability and quality (final germination percentage , abnormal seedlings, rotten grains and sold grains percentages) of wheat as shown in Tables 1 through 6.

From obtained results in Tables 1 through 6, it could be noticed that insect infestation, weight loss, abnormal seedlings, rotten grains and sold grains percentages were significantly increased due to increasing storage periods from 3 to 6 and 9 months from beginning of storage. Where, the highest percentages of these characters were resulted from storage wheat grains up to 9 months, and followed by storage wheat grains up to 6 months and lastly storage wheat grains up to 3 month. These results may be owing to instability of the temperature and humidity during storage periods. (**Attia *et al.*, 2014** and **2015)**.

Concerning final germination percentage of wheat, it was significantly decreased due to increasing storage periods up to 9 months. Where, the highest percentage of final germination were resulted from storage wheat grains up to 3 months, followed by storage wheat grains up to 6 months and lastly storage wheat grains up to 9 months. 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 (**Roberts, 1972)**. These results are in agreement with those reported by **Ramadan (2016)**.

2- Effect of packages types:

Studied packages types of wheat grains *i.e.* normal storage (stored wheat grains in normal "twisting plastic" and gunny packages) and sealing storage (stored wheat grains in polyethylene "nylon" and metal containers) significantly affected all studied characters of wheat (Tables 1 through 6).

The lowest insect infestation and weight loss percentages of wheat grains (4.15 and 6.68%) were recorded in samples of wheat grains sealed stored in polyethylene "nylon" packages, followed by sealed stored in metal containers and normal storage in gunny packages. Whereas, the highest insect infestation and weight loss percentages in wheat grains (6.90 and 16.07%) were produced from samples of wheat grains normal stored in twisting plastic. The reduction in percentage of insect infestation in wheat grains by sealed stored in metal packages may be ascribed to completely effective in maintaining seed moisture content and prevent the arrival of insects to seeds, which helps to reduce the incidence of insects. **Chattah *et al.* (2012)** confirmed these results.

The highest final germination percentage of wheat were recorded in samples of wheat grains sealed stored in polyethylene "nylon" packages, followed sealed stored in metal containers then normal storage in gunny packages and lastly normal stored in twisting plastic. While, the highest abnormal seedlings, rotten grains and sold grains percentages of wheat were produced from the samples of wheat grains normal stored in twisting plastic, followed by normal storage in gunny packages, then sealed stored in metal containers and lastly sealed stored polyethylene "nylon" packages. These results are mainly because of maintenance of moisture content during the storage period which resulted in lower respiration rate, lower metabolic activity and maintenance of higher seed vigor during storage. **Chattha *et al.* (2012) and Ramadan (2016)** confirmed these results.

3- Effect of treating with natural and chemical materials:

Statistical analysis of the obtained data exhibited that treating wheat grains before beginning of storage with natural and chemical materials i.e. control treatment (untreated grains) and treating wheat grains with thyme oil at the rate of 15%, neem oil at the rate of 20%, ascorbic acid at the rate of 500 ppm and phosphine at the rate of 8 ppm had a significant effects on storage efficiency, seed viability and quality as presented in Tables 1 through 6.

Table 1: Insect infestation percentage of wheat grains as affected by storage periods, treating grains with natural and chemical materials, packages types and their interactions.

Grains treatments	Packages types	Storage periods 3 months	6 months	9 months	Means of Grain treatments × Packages types
T_1- Without	P_1- Normal (twisting plastic)	9.00	9.75	10.50	**9.75**
	P_2- Gunny	12.00	13.25	14.50	**13.25**
	P_3- Polyethylene (nylon)	0.00	6.00	6.00	**4.00**
	P_4- Metal container	0.00	10.00	11.50	**7.16**
T_2- Thyme oil	P_1- Normal (twisting plastic)	1.00	3.00	5.00	**3.00**
	P_2- Gunny	0.00	2.50	6.50	**3.00**
	P_3- Polyethylene (nylon)	0.00	1.50	3.00	**1.50**
	P_4- Metal container	5.00	11.00	17.00	**11.00**
T_3- Neem oil	P_1- Normal (twisting plastic)	4.00	10.50	14.00	**9.50**
	P_2- Gunny	3.50	5.50	6.00	**5.00**
	P_3- Polyethylene (nylon)	0.00	0.00	0.00	**0.00**
	P_4- Metal container	0.00	0.50	0.50	**0.33**
T_4-Ascorbic acid	P_1- Normal (twisting plastic)	8.50	8.75	9.00	**8.75**
	P_2- Gunny	6.50	7.75	9.00	**7.75**
	P_3- Polyethylene (nylon)	5.00	11.25	17.50	**11.25**
	P_4- Metal container	0.00	5.50	6.50	**4.00**
T_5- Phosphine	P_1- Normal (twisting plastic)	1.00	3.50	6.00	**3.50**
	P_2- Gunny	3.00	3.25	3.50	**3.25**
	P_3- Polyethylene (nylon)	2.50	4.00	5.50	**4.00**
	P_4- Metal container	0.00	1.50	1.50	**1.00**
LSD at 5%		1.08	1.51	1.26	0.70
A-Means of Storage periods		**3.05**	**5.95**	**7.65**	
LSD at 5%		0.27			

	T_1	T_2	T_3	T_4	T_5
B- Means of Grain treatments	**8.54**	**4.62**	**3.70**	**7.93**	**2.93**
LSD at 5%	0.35				

	P_1	P_2	P_3	P_4
C- Means of packages types	**6.90**	**6.45**	**4.15**	**4.70**
LSD at 5%	0.31			
D- Interactions:				
A × B	*			
A × C	*			
B × C	*			
A × B × C	*			

Table 2: Dry weight loss percentage of wheat grains as affected by storage periods, treating grains with natural and chemical materials, packages types and their interactions.

Grains treatments	Packages types	Storage periods: 3 months	Storage periods: 6 months	Storage periods: 9 months	Means of Grain treatments × Packages types
T_1- Without	**P_1- Normal (twisting plastic)**	11.11	12.50	20.00	**14.53**
	P_2- Gunny	0.00	25.00	53.84	**26.28**
	P_3- Polyethylene (nylon)	8.33	11.11	16.66	**12.03**
	P_4- Metal container	7.69	10.34	12.50	**10.17**
T_2- Thyme oil	**P_1- Normal (twisting plastic)**	3.44	5.88	8.69	**6.00**
	P_2- Gunny	0.00	41.61	41.72	**27.77**
	P_3- Polyethylene (nylon)	0.00	0.00	0.00	**0.00**
	P_4- Metal container	5.13	6.66	8.33	**6.71**
T_3- Neem oil	**P_1- Normal (twisting plastic)**	8.10	9.09	10.00	**9.06**
	P_2- Gunny	0.00	4.34	7.14	**3.83**
	P_3- Polyethylene (nylon)	1.40	3.22	9.09	**4.57**
	P_4- Metal container	3.70	6.06	7.69	**5.81**
T_4-Ascorbic acid	**P_1- Normal (twisting plastic)**	9.09	11.11	20.00	**13.40**
	P_2- Gunny	13.04	17.75	19.04	**16.61**
	P_3- Polyethylene (nylon)	0.00	14.28	25.00	**13.09**
	P_4- Metal container	0.00	7.14	20.00	**9.04**
T_5- Phosphine	**P_1- Normal (twisting plastic)**	6.66	7.14	7.69	**7.16**
	P_2- Gunny	4.16	6.45	6.97	**5.86**
	P_3- Polyethylene (nylon)	0.00	0.00	11.11	**3.70**
	P_4- Metal container	0.00	3.63	7.69	**3.77**
LSD at 5%		1.02	1.64	1.82	1.78
A-Means of Storage periods		**4.09**	**10.16**	**15.66**	
LSD at 5%		0.69			

B- Means of Grain treatments	T_1	T_2	T_3	T_4	T_5
	15.75	**10.12**	**5.82**	**13.03**	**5.12**
LSD at 5%	0.89				

C- Means of packages types	P_1	P_2	P_3	P_4
	16.07	**10.03**	**6.68**	**7.10**
LSD at 5%	0.80			

D- Interactions:	
A × B	*
A × C	*
B × C	*
A × B × C	*

Table 3: Final germination percentage (%) as affected by storage periods, treating grains with natural and chemical materials, packages types and their interactions.

Grains treatments	Packages types	Storage periods			Means of Grain treatments × Packages types
		3 months	6 months	9 months	
T_1- Without	**P_1- Normal (twisting plastic)**	100.00	97.00	84.00	**93.66**
	P_2- Gunny	99.50	95.00	73.75	**89.41**
	P_3- Polyethylene (nylon)	96.50	95.00	84.25	**91.91**
	P_4- Metal container	100.00	99.00	83.50	**94.16**
T_2- Thyme oil	**P_1- Normal (twisting plastic)**	98.50	96.50	82.00	**92.33**
	P_2- Gunny	99.50	96.00	94.00	**96.50**
	P_3- Polyethylene (nylon)	100.00	99.50	98.00	**99.16**
	P_4- Metal container	97.25	88.50	85.00	**90.25**
T_3- Neem oil	**P_1- Normal (twisting plastic)**	99.00	93.50	89.75	**94.08**
	P_2- Gunny	100.00	100.00	90.75	**96.91**
	P_3- Polyethylene (nylon)	100.00	96.00	94.25	**96.75**
	P_4- Metal container	100.00	90.50	90.25	**93.58**
T_4-Ascorbic acid	**P_1- Normal (twisting plastic)**	92.25	85.50	73.00	**83.58**
	P_2- Gunny	100.00	99.00	90.00	**96.33**
	P_3- Polyethylene (nylon)	100.00	98.00	90.25	**96.08**
	P_4- Metal container	100.00	97.00	92.00	**96.33**
T_5-Phosphine	**P_1- Normal (twisting plastic)**	100.00	98.75	96.25	**98.33**
	P_2- Gunny	100.00	98.25	84.00	**94.08**
	P_3- Polyethylene (nylon)	100.00	99.25	93.00	**97.41**
	P_4- Metal container	100.00	100.00	98.75	**99.58**
LSD at 5%		2.14	2.71	2.97	2.44
A-Means of Storage periods		**99.12**	**96.11**	**88.33**	
LSD at 5%		1.33			

B- Means of Grain treatments	T_1	T_2	T_3	T_4	T_5
	92.29	**94.56**	**95.33**	**93.08**	**97.35**
LSD at 5%	1.72				

C- Means of packages types	P_1	P_2	P_3	P_4
	92.40	**94.65**	**96.26**	**94.78**
LSD at 5%	1.53			
D- Interactions:				
A × B	*			
A × C	*			
B × C	*			
A × B × C	*			

Table 4: Up-normal seedlings percentage (%) as affected by storage periods, treating grains with natural and chemical materials, packages types and their interactions.

Grains treatments	Packages types	Storage periods			Means of Grain treatments × Packages types
		3 months	6 months	9 months	
T_1- Without	**P_1- Normal (twisting plastic)**	0.00	1.00	6.00	**2.33**
	P_2- Gunny	0.25	0.25	9.00	**3.16**
	P_3- Polyethylene (nylon)	1.25	0.75	6.00	**2.66**
	P_4- Metal container	0.00	0.25	5.50	**1.91**
T_2- Thyme oil	**P_1- Normal (twisting plastic)**	1.50	1.50	5.00	**2.66**
	P_2- Gunny	0.50	1.00	2.00	**1.16**
	P_3- Polyethylene (nylon)	0.00	0.00	1.00	**0.33**
	P_4- Metal container	0.00	1.50	2.75	**1.41**
T_3- Neem oil	**P_1- Normal (twisting plastic)**	0.75	2.25	2.50	**1.83**
	P_2- Gunny	0.00	0.00	2.75	**0.91**
	P_3- Polyethylene (nylon)	0.00	2.25	2.50	**1.58**
	P_4- Metal container	0.00	3.00	4.00	**2.33**
T_4-Ascorbic acid	**P_1- Normal (twisting plastic)**	3.00	4.75	9.00	**5.58**
	P_2- Gunny	0.00	0.00	2.25	**0.75**
	P_3- Polyethylene (nylon)	0.00	1.25	4.25	**1.83**
	P_4- Metal container	0.00	0.75	3.25	**1.33**
T_5-Phosphine	**P_1- Normal (twisting plastic)**	0.00	0.00	0.75	**0.25**
	P_2- Gunny	0.00	1.00	2.00	**1.00**
	P_3- Polyethylene (nylon)	0.00	0.75	3.25	**1.33**
	P_4- Metal container	0.00	0.00	0.75	**0.25**
LSD at 5%		0.84	1.42	2.59	1.43
A-Means of Storage periods		**0.36**	**1.11**	**3.72**	
LSD at 5%		0.55			

	T_1	T_2	T_3	T_4	T_5
B- Means of Grain treatments	**2.52**	**1.66**	**1.39**	**2.37**	**0.70**
LSD at 5%	0.72				

	P_1	P_2	P_3	P_4
C- Means of packages types	**2.53**	**1.55**	**1.40**	**1.45**
LSD at 5%	0.64			

D- Interactions:	
A × B	*
A × C	*
B × C	*
A × B × C	*

Table 5: Rotten seeds percentage (%) as affected by storage periods, treating grains with natural and chemical materials, packages types and their interactions.

Grains treatments	Packages types	Storage periods: 3 months	Storage periods: 6 months	Storage periods: 9 months	Means of Grain treatments × Packages types
T_1- Without	**P_1- Normal (twisting plastic)**	0.00	1.25	5.00	**2.08**
	P_2- Gunny	0.25	2.00	8.00	**3.41**
	P_3- Polyethylene (nylon)	1.50	1.75	4.75	**2.66**
	P_4- Metal container	0.00	0.25	5.50	**1.91**
T_2- Thyme oil	**P_1- Normal (twisting plastic)**	0.00	1.50	2.00	**1.16**
	P_2- Gunny	0.00	1.50	2.00	**1.16**
	P_3- Polyethylene (nylon)	0.00	0.00	1.25	**0.41**
	P_4- Metal container	0.25	5.50	7.00	**4.25**
T_3- Neem oil	**P_1- Normal (twisting plastic)**	0.25	1.50	1.75	**1.16**
	P_2- Gunny	0.00	0.00	1.25	**0.41**
	P_3- Polyethylene (nylon)	0.00	1.00	1.25	**0.75**
	P_4- Metal container	0.00	1.50	3.50	**1.66**
T_4-Ascorbic acid	**P_1- Normal (twisting plastic)**	2.50	5.25	7.00	**4.91**
	P_2- Gunny	0.00	0.50	3.25	**1.25**
	P_3- Polyethylene (nylon)	0.00	0.25	3.00	**1.08**
	P_4- Metal container	0.00	1.00	2.50	**1.16**
T_5-Phosphine	**P_1- Normal (twisting plastic)**	0.00	0.50	1.00	**0.50**
	P_2- Gunny	0.00	0.50	2.50	**1.00**
	P_3- Polyethylene (nylon)	0.00	1.00	1.75	**0.91**
	P_4- Metal container	0.00	0.00	0.25	**0.08**
LSD at 5%		0.59	2.60	1.65	1.48
A-Means of Storage periods		**0.23**	**1.33**	**3.22**	
LSD at 5%		0.57			

B- Means of Grain treatments	T_1	T_2	T_3	T_4	T_5
	2.52	**1.75**	**1.00**	**2.10**	**0.62**
LSD at 5%	0.74				

C- Means of packages types	P_1	P_2	P_3	P_4
	1.96	**1.81**	**1.16**	**1.45**
LSD at 5%	0.66			

D- Interactions:	
A × B	*
A × C	*
B × C	*
A × B × C	*

Table 6: Sold grains percentage (%) as affected by storage periods, treating grains with natural and chemical materials, packages types and their interactions.

Grains treatments	Packages types	Storage periods 3 months	Storage periods 6 months	Storage periods 9 months	Means of Grain treatments × Packages types
T_1- Without	**P_1- Normal (twisting plastic)**	0.00	0.75	5.00	**1.91**
	P_2- Gunny	0.00	2.75	9.25	**4.00**
	P_3- Polyethylene (nylon)	0.75	5.00	2.50	**2.75**
	P_4- Metal container	0.00	0.50	5.50	**2.00**
T_2- Thyme oil	**P_1- Normal (twisting plastic)**	0.00	0.50	15.00	**5.16**
	P_2- Gunny	0.00	1.50	3.00	**1.50**
	P_3- Polyethylene (nylon)	0.00	0.50	0.50	**0.33**
	P_4- Metal container	1.00	3.25	12.00	**5.41**
T_3- Neem oil	**P_1- Normal (twisting plastic)**	0.00	3.50	6.50	**3.33**
	P_2- Gunny	0.00	0.00	5.25	**1.75**
	P_3- Polyethylene (nylon)	0.00	1.25	2.50	**1.25**
	P_4- Metal container	0.00	3.00	4.25	**2.41**
T_4-Ascorbic acid	**P_1- Normal (twisting plastic)**	2.25	4.50	11.00	**5.91**
	P_2- Gunny	0.00	0.50	4.50	**1.66**
	P_3- Polyethylene (nylon)	0.00	0.50	2.50	**1.00**
	P_4- Metal container	0.00	1.25	2.25	**1.16**
T_5-Phosphine	**P_1- Normal (twisting plastic)**	0.00	0.00	2.75	**0.91**
	P_2- Gunny	0.00	0.25	12.50	**4.25**
	P_3- Polyethylene (nylon)	0.00	0.00	2.00	**0.66**
	P_4- Metal container	0.00	0.00	0.25	**0.08**
LSD at 5%		0.77	2.73	3.72	2.08
A-Means of Storage periods		**0.20**	**1.47**	**5.45**	
LSD at 5%		0.80			

B- Means of Grain treatments	T_1	T_2	T_3	T_4	T_5
	3.10	**2.43**	**2.18**	**2.66**	**1.47**
LSD at 5%	1.04				

C- Means of packages types	P_1	P_2	P_3	P_4
	3.45	**2.63**	**1.20**	**2.21**
LSD at 5%	0.93			

D- Interactions:	
A × B	*
A × C	*
B × C	*
A × B × C	*

The highest insect infestation, weight loss, abnormal seedlings, rotten grains and sold grains percentages (8.54, 15.75, 2.52, 2.52 and 3.10 %) and the lowest final germination percentage (92.29 %) of wheat grains were resulted from wheat grains stored without any treatment (control treatment). Whereas, the lowest insect infestation, weight loss, abnormal seedlings, rotten grains and sold grains percentages (2.93, 5.12, 0.70, 0.62 and 1.47%) and the highest final germination percentage (97.35 %) of wheat grains were produced from treating with phosphine at the rate of 8 ppm. The second best treatment was treating with neem oil at the rate of 20% and followed by treating with thyme oil at the rate of 15% and lastly treating with ascorbic acid at the rate of 500 ppm. The favourable role of treating wheat grains before storage with phosphine at the rate of 7 tablets/m^3 which reduced insect infestation percentage may be ascribed to phosphine gas (PH_3), that formed by react between tablets of aluminum phosphide placed in grain and water in the air, is prevented insects piercing and entering into seeds by poison effect. Moreover, 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. In addition, the reason that caused reduce wheat grains to infect with insects due to treatment with neem oil before initiation of storage may be due to neem seed oil is considered as antifeedant, repellant, growth disrupting and larvicidal properties against a large number of pests **(Mathur, 2013)**. These findings are in agreement with those reported by **Badawi *et al.* (2014), Attia *et al.* (2015), Seadh *et al.* (2015) and Ramadan (2016)**.

4- Effect of the interactions:

There are many significant effects of the interactions among studied factors on studied characters. We present only the significant interaction between storage periods and packages types (Fig. 1) and storage periods and treating grains with natural and chemical materials (Fig. 2) on final germination percentage.

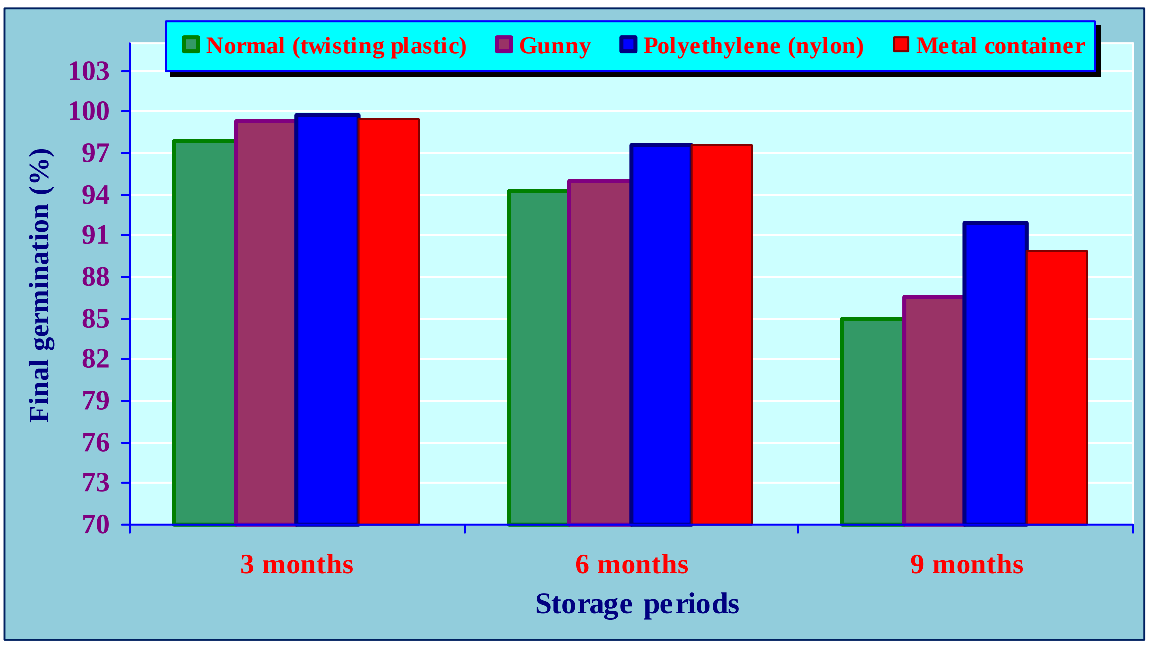

Fig. 1: Final germination percentage (%) as affected by the interaction between storage periods and packages types.

The best results of final germination percentage were obtained from samples of wheat grains sealed stored in polyethylene "nylon" packages, followed sealed stored in metal containers, then normal storage in gunny packages and lastly normal stored in twisting plastic for 3 or 6 or 9 months (Fig. 1). The best results of final germination percentage were obtained from samples of wheat grains treating with phosphine at the rate of 8 ppm, followed by treating with neem oil at the rate of 20% and followed by treating with thyme oil at the rate of 15% and lastly treating with ascorbic acid at the rate of 500 ppm for 3 or 6 or 9 months (Fig. 2).

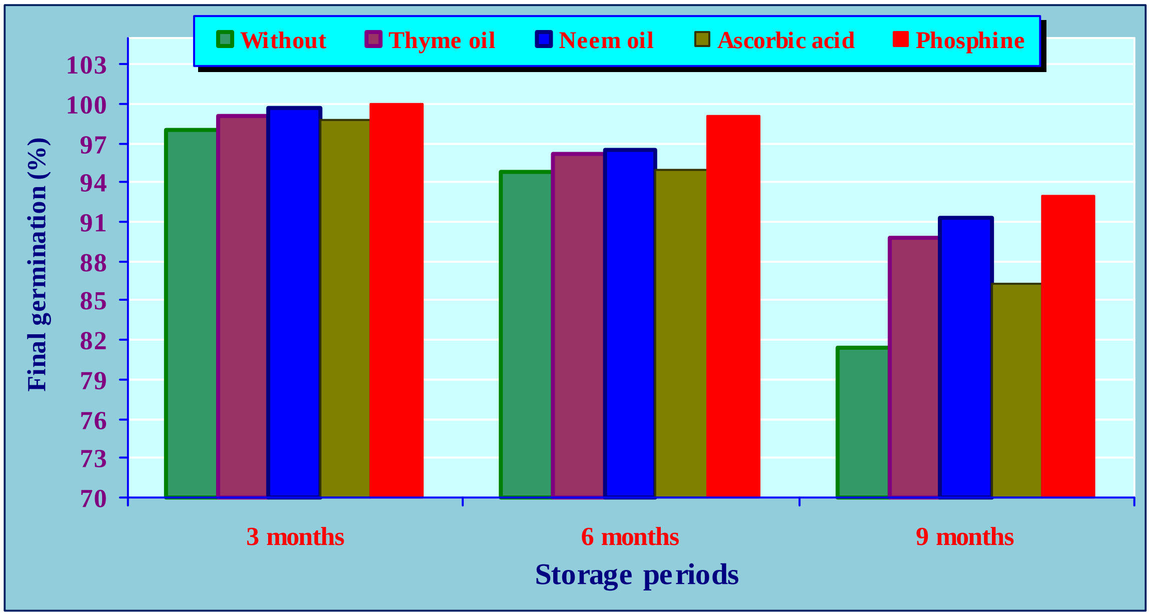

Fig. 2: Final germination percentage (%) as affected by the interaction between storage periods and treating grains with natural and chemical materials.

Conclusion

This study recommended that treating wheat grains with phosphine at the rate of 8 ppm (as a chemical material) or neem oil at the rate of 20% (as a natural material), before storage in polyethylene or metal packages under the environmental conditions of the experiment in Mansoura, Dakahlia Governorate, Egypt.

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