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Research Article
Some Factors Affect Storage Efficacy and Germination Parameters of Rice

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Abstract
Background and Objective: The high post-harvest losses of grain ranging between 35 and 46% are attributed to the adverse weather conditions that favour growth of a number of insect pest and mites harmful to stored products, which reducing the quantity and/or quality of the stored products. Thus, this study aimed to evaluate the effect of packages types and grain treatments on storage efficacy and germination and seedlings parameters of rice during different storage periods (3, 6, 9 and 12 months after harvesting). **Materials and Methods:** A laboratory experiment was conducted at Agronomy Department Laboratory of Seed Testing, Faculty of Agriculture, Mansoura University, Egypt. The experiment was arranged in a factorial experiment in randomized complete block design with four replications. **Results:** Increasing storage periods of rice grain from 3, 6, 9 and 12 months after harvesting significantly affected storage efficacy character (insect infestation percentage), germination parameters (final germination, abnormal seedlings, sold and rotten grains percentages) and seedling parameters (root and shoot lengths, seedlings dry weight and seedling vigor index). The best results of storage efficacy, germination and seedlings parameters of rice recorded when sealed stored in metal packages, followed sealed stored in polyethylene, then unsealed stored in light cloth and lastly unsealed stored in paper packages. The lowest percentage of insect infestation and maximum values of germination and seedling parameters were obtained from fumigation rice grains before storage with phosphine at the rate of 5 tablets/m^3. **Conclusion:** This study concluded that fumigation rice grains before storage in metal packages with phosphine.

Key words: Rice, storage periods, storage methods, packages types, neem oil, phosphine, storage efficacy, germination and seedlings parameters

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple cereal foods consumed by about half of the world's population, supplies adequate energy in the form of calories and is a good source of thiamine, riboflavin and niacin[1]. During storage, grain quality remain high at the initial level or decline to a level that may make the grain unacceptable for planting purpose what is related to many determinants: environmental conditions during grain production, pests, temperature and relative humidity of the air and the storage environment, grain moisture content, water content in the storage, grain characteristics, packing materials, storage periods, fungicidal grain treatments, varieties, gas exchange and characteristics of the grain skin[2].

Storage period have a enormous influence on the quality of rice seeds. Where, the goal of storing is to provide optimum preservation of physiological and physical characteristics of grain[3]. Marques *et al*.[4] found that Seleta cultivar showed higher dormancy, which was surpassed during storage 3, 6, 9 and 12 months of beginning storage regardless of environment conservation. Attia *et al*.[5] revealed that increasing storage periods of paddy rice from 2-4 and 6 months from beginning of storage significantly increased storage efficacy. Bhardwaj and Sharma[6] indicated that impacts of storage period of paddy rice under different environments have profound effect on storage in terms of decreased bulk density and germination characters. Seadh *et al*.[7] reported that the numbers of insects and yellow grains of milled rice significantly increased due to increasing storage periods from 2-4 and 6 months. Tsado *et al*.[8] stated that at long storage periods, the major determinant of grain fissures and breakages of paddy rice was recorded. Hence, short storage periods of paddy rice was recommended to minimize fissures and breakages of milled rice. Sadaka *et al*.[9] revealed that safe grain storage periods represent the maximum allowable number of days to store grain without major deterioration. Grain deterioration, which usually expressed as percent of dry matter loss, resulted in decreases in its value and quality. El-Dalil[10] indicated that storage grains of Giza 179 rice cultivar for nine months gave the highest values for hulling (%), milling (%), broken (%), water uptake, cooking time, protein amylase and elongation. Jungtheerapanich *et al*.[11] indicated that increasing storage period of paddy rice led to decrease in breakdown grains and an increase in head rice yield.

In order to prevent the quantitative and qualitative losses due to several biotic and abiotic factors during storage, several methods are being adopted such as grain treatment with plant products or suitable chemicals and storing in safe containers, besides sanitation of the storage place. Seadh *et al*.[7] 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. Jyoti[12] revealed that paddy rice grain stored in vacuum polythene bags was proved to be superior of viability compared with grain stored in non-vacuum polythene bags or jute bags. Mutinda *et al*.[13] showed that packaging material (polythene, khaki, cheese cloth, polypropylene sack and gunny bags) had a significant effect on germination and vigour rice. At room temperature, grain stored in polythene bag had the highest germination. Naik and Chetti[14] found that among the containers, vacuum packaged bags recorded higher score for appearance, color, flavour, texture, taste and overall acceptability of cooked rice compared to all other treatments. Lower score was observed in gunny bags, followed by cloth bags. Silva *et al*.[15] concluded that during storage, the greatest changes in the physiological quality of rice grains were verified in the polyethylene bag package.

The extent of storability is influenced by storage methods. In general grain stored in moisture impervious sealed containers provide suitable environment for storage, offer protection against contamination and also acts as a barrier against the escape of grain treatment chemicals than in moisture pervious containers. Neem oil or neem grain oil is a brownish yellow color, liquid, with smell of garlic. Azadirachtin of neem oil is a famous natural anti-feedent, growth regulator and ovi-positional repellent for insects, as a major active ingredient which make it a perfect alternative to chemical pesticides. Tariq *et al*.[16] concluded that the insect growth inhibition was increased by increasing the dose of neem grain powder from 0.5-1.0 and 2.0% (w/w). Jyoti[12] revealed that paddy rice grain treated with castor oil was proved to be superior of viability compared with grain treated with neem cake at 10 g kg^{-1} seed, Thiram at 2 g kg^{-1} or untreated seeds. Rawat *et al*.[17] revealed neem oil concentrations above 2% were significantly inhibited mycelia growth of fungi. Waris *et al*.[18] indicated that there was significant differences among all the tested plant extracts and oil in both the 10% and 20% concentration against the pathogens.

Fumigation is a technique employed to eliminate insect pests in stored grains by using gas. Phosphine fumigation offers a cost-effective method of treating grain so that insects are controlled. Niu *et al*.[19] indicated that the germination rate (GR), germination potential (GP) and germination index (GI) of rice grains markedly decreased after phosphine exposure. Overall, the effect of phosphine on rice grains is different from what has been reported previously for insects and mammals. Attia *et al*.[5] showed that the best results of storage efficacy of paddy rice were obtained when treating with phosphine at the rate of 6 balls t^{-1}, followed treating with phosphine at the rate of 4 balls t^{-1}, then phosphine at the rate of 2 balls t^{-1}. Seadh *et al.*[7] pointed out that the best results of physical characters of milled rice obtained when treating with phosphine at the rate of 6 balls t^{-1}, followed treating with phosphine at the rate of 4 balls t^{-1}, then treating with phosphine at the rate of 2 balls t^{-1}.

Therefore, this investigation was established to study the effect of packages types and grain treatments and their interaction on storage efficacy and germination and seedlings parameters of rice during different storage periods (3, 6, 9 and 12 months after harvesting) under the environmental conditions of Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

This research was conducted at Agronomy Department Laboratory of Grain Testing, Faculty of Agriculture, Mansoura University, Egypt to evaluate the effect of packages types and grain treatments and their interaction on storage efficacy and germination and seedlings parameters of rice crop during different storage periods.

The experiment was arranged in a factorial experiment in randomized complete block design (RCBD) with four replications after harvesting time (2016 season).

The first factor contained different storage periods (3, 6, 9 and 12 months after harvesting). The second factor included packages types i.e., unsealing storage (stored in light cloth packages and paper packages) and sealing storage (stored in polyethylene and metal packages). The third factor was grain treatment of rice at the beginning of storage i.e., control treatment (untreated seed), treating grain with neem oil at the rate of 10% and phosphine at the rate of 5 tablets m^{-3}.

About 500 g of rice grains with 12-13% moisture content in each replicate were stored in various packages as formerly mentioned and then treated with various rates of neem oil and phosphine for 3 days and then start of storage. The studied rice Giza 178 cultivar was obtained directly after harvesting from the Agricultural Research Station Farm in Tag Al-Ezz, Dakahlia Governorate, Agricultural Research Center, Egypt.

Studied characters

Storage efficacy character

Insect infestation percentage: After each storage period (3, 6, 9 and 12 months after harvesting) four replicates 100 grain from each treatment of rice were manually picked from each package from different depth randomly for inspection. Grain which having holes or infestation were collected also, the grain which showed signs of insect damage were considered as infested. The infestation level was expressed as number and percentage damage grain according to the Equation of Jood *et al.*[20]:

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

Standard germination test: Random sample of 100 grain of rice for each treatment were allowed to germinate under the environmental conditions of Agronomy Department Laboratory of Grain Testing, Faculty of Agriculture, Mansoura University, Egypt at the end of each storage period as the rules of International Seed Testing Association[21] on top filter paper in sterilized Petri dishes (14 cm diameter) and each Petri dish contains 25 seeds.

The germinated grains were counted and first count defined as the number of germinated grains at the 4th day. Then, every 24 h the number of germinated grains were counted until the end of germination test (8 days) to recorded:

Final germination percentage (FG %): Normal seedlings of each replicate were counted at the end of standard germination test and expressed as percentage according to the following equation described by ISTA[21]:

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

Abnormal seedlings (%): It was counted and expressed by the percentage of abnormal seedlings at the end of germination test according to ISTA[21].

Sold grains (%): It was counted and expressed by the percentage of rotten grains at the end of germination test according to ISTA[21].

Rotten grains (%): It was counted and expressed by the percentage of hard grains at the end of germination test according to ISTA[21].

Seedling parameters

Root length: Averages of root length of 10 seedlings of both rice were taken at random per each replicate from the grain to the tip of the root and recorded and expressed in centimeters (cm) as the root length at the end of standard germination test.

Shoot length: Averages of shoot length of 10 seedlings of both rice were taken at random per each replicate from the grain to the tip of the leaf blade and expressed in centimeters as the shoot length at the end of standard germination test.

Seedlings dry weight: Weight of 10 seedling of both rice taken at random per replicate were recorded and expressed in gram (g) after oven drying at 70°C until constant weight[22].

Seedling vigor index (SVI): It was calculated according to the equation as suggested by Abdul-Baki and Anderson[23]:

$$SVI = \frac{(\text{Root length} + \text{shoot length}) \times \text{Germination (\%)}}{100}$$

Data were subjected to the statistical analysis according to the technique of analysis of variance (ANOVA) for the factorial experiment in completely randomized design (CRD) as published by Gomez and Gomez[24] 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[25].

RESULTS

Effect of storage periods: Increasing storage periods of rice grains from 3 to 6, 9 and 12 months after harvesting significantly affected storage efficacy character (insect infestation (%)), germination parameters (final germination, abnormal seedlings, sold and rotten grains (%)) and seedling parameters (root and shoot lengths, seedlings dry weight and seedling vigor index) of rice as shown from data in Table 1 and 2.

From obtained results in Table 1 and 2, it could be noticed that insect infestation, abnormal seedlings, sold and rotten grains (%) of rice grains were significantly increased due to increasing storage periods from 3 to 6, 9 and 12 months after harvesting. Where, the highest percentages of insect infestation, abnormal seedlings, sold and rotten grains percentages of rice grains were resulted from storage rice grains up to 12 months, followed by storage rice grains up to 9 months, then storage rice grains up to 6 months and lastly storage rice grains up to 3 months.

Table 1: Insect infestation, final germination, abnormal seedlings, sold and rotten grains percentages of rice as affected by storage periods, packages types and grains treatments

Characters treatments	Insect infestation (%)	Final germination (%)	Abnormal seedlings (%)	Sold grains (%)	Rotten grains (%)
Storage periods					
3 months	8.27	89.59	3.67	3.70	2.33
6 months	8.68	85.52	6.96	4.72	2.79
9 months	9.15	82.76	9.23	5.66	3.02
12 months	9.54	78.99	10.86	6.92	3.21
F-test	*	*	*	*	*
LSD at 5%	0.02	0.12	0.14	0.12	0.21
Packages types					
Light cloth	8.96	84.10	7.83	5.36	2.88
Paper	9.06	83.81	8.06	5.54	3.21
Polyethylene	8.86	84.42	7.49	5.19	2.69
Metal	8.75	84.53	7.34	4.91	2.56
F-test	*	*	*	*	*
LSD at 5%	0.01	0.11	0.13	0.11	0.19
Grains treatments					
Untreated	9.90	82.15	9.83	7.24	6.72
Neem oil	9.08	84.71	8.21	6.03	1.03
Phosphine	7.74	85.79	4.99	2.48	0.76
F-test	*	*	*	*	*
LSD at 5%	0.01	0.10	0.12	0.10	0.18
Interactions					
A×B	*	NS	*	*	NS
A×C	*	*	*	*	NS
B×C	*	*	NS	NS	NS
A×B×C	*	*	*	NS	NS

Table 2: Root and shoot lengths, seedlings dry weight and seedling vigor index (SVI) of rice seedlings as affected by storage periods, packages types and grains treatments

Characters treatments	Root length (cm)	Shoot length (cm)	Seedlings dry weight (g)	SVI
Storage periods				
3 months	6.55	6.48	0.179	11.69
6 months	6.05	6.06	0.132	10.38
9 months	5.42	5.56	0.100	9.10
12 months	4.68	4.98	0.070	7.64
F-test	*	*	*	*
LSD at 5%	0.02	0.02	0.029	0.02
Packages types				
Light cloth	5.61	5.71	0.112	9.59
Paper	5.45	5.59	0.125	9.31
Polyethylene	5.76	5.83	0.119	9.85
Metal	5.88	5.95	0.126	10.07
F-test	*	*	NS	*
LSD at 5%	0.01	0.01	-	0.02
Grains treatments				
Untreated	4.79	5.38	0.091	8.39
Neem oil	6.02	5.79	0.131	10.06
Phosphine	6.22	6.14	0.139	10.66
F-test	*	*	*	*
LSD at 5%	0.01	0.01	0.025	0.01
Interactions				
A×B	*	*	NS	*
A×C	*	*	NS	*
B×C	*	*	NS	NS
A×B×C	*	*	NS	NS

Concerning final germination (%) and seedling parameters of rice (root and shoot lengths, seedlings dry weight and seedling vigor index), it were significantly decreased due to increasing storage periods from 3-6, 9 and 12 months after harvesting. Where, the highest percentage of final germination and the highest values of root and shoot lengths, seedlings dry weight and seedling vigor index (SVI) of rice seedlings were resulted from storage rice grains up to 3 months, followed by storage rice grains up to 6 months, then storage rice grains up to 9 months and lastly storage rice grains up to 12 months.

Effect of packages types: Studied packages types of rice grains i.e., unsealing storage (stored in light cloth packages and paper packages) and sealing storage (stored in polyethylene and metal packages) significantly affected storage efficacy character (insect infestation (%)), germination parameters (final germination, abnormal seedlings, sold and rotten grains (%)) and seedling parameters (root and shoot lengths and seedling vigor index) of rice (Table 1 and 2).

The lowest insect infestation, abnormal seedlings, sold and rotten grains percentages of rice grains were recorded in samples of rice grains sealed stored in metal packages, followed sealed stored in polyethylene. Whereas, the highest insect infestation, abnormal seedlings, sold and rotten grains (%) of rice grains were produced from samples of rice grains unsealing storage in paper packages. The highest final germination (%) and seedling parameters of rice (root and shoot lengths, seedlings dry weight and seedling vigor index) of rice were recorded in samples of rice grains sealed stored in metal packages, followed that sealed stored in polyethylene. While, the lowest final germination percentage and seedling parameters of rice were produced from the samples of rice grains unsealing storage in paper packages.

Effect of grains treatments: Statistical analysis of the obtained data exhibited that studied grain treatment of rice at the beginning of storage i.e., control treatment (untreated seed), treating grain with neem oil at the rate of 10% and phosphine at the rate of 5 tablets m^{-3} had a significant effect on storage efficacy character (insect infestation (%)), germination parameters (final germination, abnormal seedlings, sold and rotten grains (%)) and seedling parameters (root and shoot lengths and seedling vigor index) of rice (Table 1 and 2).

The highest insect infestation, abnormal seedlings, sold and rotten grains percentages of rice grains were resulted from rice grains stored without treatment (control treatment). Whereas, the lowest insect infestation, abnormal seedlings, sold and rotten grains percentages of rice grains were produced from treating rice grains with phosphine at the rate of 5 tablets m^{-3}. The second best treatment was treating rice grains with neem oil at the rate of 10%. The highest final germination (%) and seedling parameters of rice (root and shoot lengths, seedlings dry weight and seedling vigor index) of rice were produced from treating rice grains with phosphine at the rate of 5 tablets m^{-3}. However, treating rice grains with neem oil at the rate of 10% ranked after aforementioned treatment. The lowest final germination percentage and seedling parameters of rice were resulted from rice grains stored without treatment (control treatment).

Effect of the interactions: There are many significant effects of the interactions among studied factors on studied characters. It present only the significant three way interaction among storage periods, packages types and grains treatments on studied characters as presented in Table 1 and 2.

Concerning the third interaction among studied factors i.e., storage periods, packages types and grains treatments, it exhibited significant effect on insect infestation, final germination, abnormal seedlings, root and shoot lengths of

Table 3: Insect infestation of rice grains as affected by the interaction among storage periods, packages types and grains treatments

Storage periods (months)	Packages types	Grains treatments Untreated	Neem oil	Phosphine
3	Light cloth	9.44	8.53	7.00
	Paper	9.50	8.63	7.20
	Polyethylene	9.34	8.37	6.92
	Metal	9.20	8.18	6.88
6	Light cloth	9.75	8.85	7.56
	Paper	9.83	9.00	7.68
	Polyethylene	9.64	8.79	7.43
	Metal	9.56	8.73	7.34
9	Light cloth	10.15	9.44	8.02
	Paper	10.27	9.49	8.19
	Polyethylene	10.03	9.39	7.89
	Metal	9.92	9.27	7.76
12	Light cloth	10.45	9.70	8.61
	Paper	10.49	9.78	8.71
	Polyethylene	10.42	9.63	8.44
	Metal	10.36	9.56	8.31
F-test		*		
LSD at 5%		0.03		

Table 4: Final germination (%) of rice as affected by the interaction among storage periods, packages types and grains treatments

Storage periods (months)	Packages types	Grains treatments Untreated	Neem oil	Phosphine
3	Light cloth	87.89	89.78	90.85
	Paper	87.67	89.72	90.58
	Polyethylene	88.07	89.88	90.99
	Metal	88.20	90.13	91.37
6	Light cloth	83.24	85.99	86.96
	Paper	82.72	85.55	86.87
	Polyethylene	83.85	86.29	87.07
	Metal	83.80	86.54	87.31
9	Light cloth	80.32	83.18	84.43
	Paper	79.73	82.93	84.25
	Polyethylene	80.99	83.45	84.83
	Metal	80.69	83.59	84.77
12	Light cloth	76.59	79.57	80.40
	Paper	76.36	79.30	80.10
	Polyethylene	77.24	79.71	80.73
	Metal	77.06	79.82	81.05
F-test		*		
LSD at 5%		0.41		

rice. The best results of insect infestation (Table 3), final germination (Table 4), abnormal seedlings (Table 5), root length (Table 6) and shoot length (Table 7) of rice were obtained from samples of rice grains sealed stored in metal packages and fumigation with phosphine at the rate of 5 tablets m^{-3} for 3 or 6 months. Although, the highest insect infestation percentage and lowest final germination, abnormal seedlings, root and shoot lengths of rice were obtained from samples of rice and grains unsealed stored in paper packages without treatment with phosphine or neem oil for 12 months (Table 5-8).

Table 5: Abnormal seedlings percentage of rice as affected by the interaction among storage periods, packages types and grains treatments

Storage periods (months)	Packages types	Grains treatments Untreated	Neem oil	Phosphine
3	Light cloth	5.97	4.33	1.52
	Paper	5.97	4.87	1.77
	Polyethylene	5.11	3.87	1.14
	Metal	5.15	3.49	0.80
6	Light cloth	9.39	7.93	4.26
	Paper	9.78	7.65	4.57
	Polyethylene	8.48	7.70	4.03
	Metal	8.51	7.33	3.88
9	Light cloth	11.34	9.58	6.76
	Paper	11.84	10.09	7.18
	Polyethylene	11.00	9.85	6.38
	Metal	11.20	9.52	5.99
12	Light cloth	13.65	11.29	7.89
	Paper	13.06	11.68	8.27
	Polyethylene	13.43	11.11	7.80
	Metal	13.42	11.09	7.63
F-test		*		
LSD at 5%		0.50		

Table 6: Root length of rice seedlings as affected by the interaction among storage periods, packages types and grains treatments

Storage periods (months)	Packages types	Grains treatments Untreated	Neem oil	Phosphine
3	Light cloth	5.47	6.84	7.21
	Paper	5.34	6.75	7.08
	Polyethylene	5.54	6.94	7.36
	Metal	5.62	7.04	7.45
6	Light cloth	4.94	6.51	6.65
	Paper	4.83	6.27	6.34
	Polyethylene	5.10	6.59	6.72
	Metal	5.20	6.66	6.85
9	Light cloth	4.55	5.66	5.77
	Paper	4.45	5.40	5.50
	Polyethylene	4.70	5.90	6.02
	Metal	4.76	6.12	6.16
12	Light cloth	3.91	4.81	5.03
	Paper	3.82	4.67	4.92
	Polyethylene	4.10	4.98	5.12
	Metal	4.29	5.19	5.29
F-test		*		
LSD at 5%		0.04		

DISCUSSION

The grain 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 grain and loss of germination. These results are in agreement with those reported by Marques *et al.*[4], Tsado *et al.*[8], Sadaka *et al.*[9] and Jungtheerapanich *et al.*[11].

Table 7: Shoot length of rice seedlings as affected by the interaction among storage periods, packages types and grains treatments

Storage periods (months)	Packages types	Grains treatments Untreated	Neem oil	Phosphine
3	Light cloth	5.86	6.46	6.91
	Paper	5.78	6.34	6.74
	Polyethylene	5.99	6.60	7.03
	Metal	6.17	6.75	7.12
6	Light cloth	5.57	6.04	6.40
	Paper	5.49	5.93	6.30
	Polyethylene	5.66	6.15	6.55
	Metal	5.72	6.24	6.63
9	Light cloth	5.24	5.49	5.74
	Paper	5.07	5.34	5.58
	Polyethylene	5.30	5.64	5.97
	Metal	5.36	5.82	6.18
12	Light cloth	4.64	4.91	5.21
	Paper	4.50	4.82	5.16
	Polyethylene	4.80	4.99	5.28
	Metal	4.89	5.18	5.41
F-test		*		
LSD at 5%		0.04		

The reduction in percentage of insect infestation in rice grains by sealed stored in metal packages may be ascribed to completely effective in maintaining grain moisture content and prevent the arrival of insects to seeds, which helps to reduce the incidence of insects. Seadh *et al.*[7] and Jyoti[12] confirmed these results. These results also mainly because of maintenance of moisture content during the storage period which resulted in lower respiration rate, lower metabolic activity and maintenance of higher grain vigour during storage. Mutinda *et al.*[13] and Silva *et al.*[15] confirmed these results.

The favourable role of treating rice grains before storage with phosphine at the rate of 5 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 grains 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. These findings are in agreement with those reported by Arria *et al.*[5], Seadh *et al.*[7] and Niu *et al.*[19].

The increasing in final germination percentage and seedling parameters of rice by treating grains with phosphine at the rate of 5 tablets m^{-3} probably due to efficiency of phosphine at these concentrations in reduction damaged grains and a grains weight loss percentages as result of its poison effect, prevented the insects piercing and entering into grains, consequently increasing germination and seedlings parameters. These results are in conformity with those stated by Arria *et al.*[5], Seadh *et al.*[7] and Niu *et al.*[19].

CONCLUSION

Thus, it could be concluded that fumigation rice grains before stored in metal packages with phosphine (5 tablets m^{-3}) under conditions similar to this research.

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