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Research Article

Effect of phosphine and oil neem on storage efficacy and technological characters of paddy rice

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Abstract

A laboratory experiments was conducted under the laboratory conditions of the Experimental Station of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt, from 25th December, 2013 to 25th June, 2014 to study the effect of phosphine (as a chemical insecticide) and oil neem (as natural plant oil) rates on storage efficacy and technological characters of paddy rice Sakha 101 cultivar during different storage periods (2, 4 and 6 months from beginning of storage). The most important results can be summarized as follows:

- Storage efficacy, grain length after cooking and gelatinization temperature (GT) were significantly increased due to increasing storage periods. Hulling, milling, head rice (Grading), amylose and grain shape percentages were significantly decreased as a result of increasing storage periods.
- The best results of storage efficacy and technological characters of paddy 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 neem oil at the rate of 9 % and phosphine at the rate of 2 balls/ton.

It can be recommended that treating paddy rice grains before storage with phosphine insecticide at the rate of 4 - 6 balls/ton or neem oil at the rate of 9 % to achieve the best possible storage efficacy and technological characters under the environmental conditions of Mansoura, Egypt.

Keywords: Paddy rice, Chemical insecticides, Phosphine, Neem oil, Storage efficacy, Technological characters.

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 (**Zhu *et al*., 2010**).

During storage, the paddy rice is attacked by insect pests including the Angoumois grain moth, *Sitotroga cerealella* Olivier, the lesser grain borer, *Rhyzopertha dominica* F., the rust-red flour beetle, *Tribolium castaneum* Herbst, the rice weevil, *Sitophilus oryzae* L. and the grain beetles *Cryptolestes spp.* (**Prakash et al., 1987**). Control of pests of stored products, particularly in large bulks, is essential if grain quality and condition are to be maintained. Where, grain contaminated with insects is unacceptable to many markets and export standards require that there be no live insects detected in grain destined for export. Chemical control measures as the principal part of integrated management. Pesticide application frequency can be reduced if combined with other control procedures in an integrated pest management programme, therefore reducing the risk of resistance development (**Soderland and Bloomquist, 1990**).

Altered susceptibility or resistance of various populations of harmful insects is the most restricting factor in chemical control as it may lead to excessive use of insecticides and to detrimental economic and ecological effects, plus a negative impact on human health (**Subramanyam and Hagstrum, 1996**). Fumigation with phosphine (PH_3, hydrogen phosphide) has the potential to disinfest stored grain. Phosphine fumigation offers a cost-effective method of treating grain so that insects are controlled. **Banks (1991)** revealed that formulations of aluminum or magnesium phosphide fumigant in the form of tablets or pellets are placed in grain where they react with water in the air to produce the fumigant gas, phosphine (PH_3). The number of days required for the gas to be generated from the solid formulation depends on temperature, moisture and the brand of fumigant. The gas is lost from the interstitial spaces between the grain by either sorption into the grain or loss (escape) from the bin. **Collins et al. (2005)** reported that phosphine is relatively easy to use, versatile, cheap, and accepted internationally as a low-residue treatment. Although a number of alternative fumigants are being developed for stored grain, for example, carbonyl sulphide, hydrogen cyanide and ethyl formate none of these can match the combined properties of phosphine. **Lorini *et al.* (2011)** concluded that the release of gas in phosphinyl starts soon after the availability of the tablets on the environment, increasing the concentration over time until complete dissolution of the tablet steaming.

Neem oil is used to manufacture neem oil insecticide because it contains azadirachtin which effects over 600 species of pests including insects, nematodes, fungi and viruses and is completely safe to non target organisms like beneficial predators, honey bees, pollinators, fish, birds, cattle and human beings. 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. **Pinheiro and Quintela (2010)** showed that neem oil formulations, at ≥ 1% (v/v) concentration, can be used to reduce the quantitative and qualitative damages caused by *Oebalus poecilus* Dallas. in lowland rice. **Kumawat and Bhanwar (2013)** found that the maximum protection of insects was obtained by neem oil, where no grain damage was recorded by neem oil treated grains and no adverse effect of plant oils was observed on seed viability for up to 270 days of treatment.

Therefore, this investigation was established to study the effect of phosphine (as a chemical insecticide), oil neem (as a plant oil) on storage efficacy and technological characters of paddy rice Sakha 101 cultivar during different storage periods (2, 4 and 6 months from beginning of storage) under the environmental conditions of Dakahlia Governorate, Egypt..

Materials and Methods

A laboratory experiments was conducted under the laboratory conditions of the Experimental Station of Agronomy Department, Faculty of Agriculture, Mansoura University, Egypt, from 25th December, 2013 to 25th June, 2014. The purpose of this experiment was to appraise the effect of phosphine (as a chemical insecticide) and oil neem (as natural plant oil) rates on storage efficacy and technological characters of paddy rice Sakha 101 cultivar during different storage periods (2, 4 and 6 months from beginning of storage).

The treatments were arranged in randomized complete block design (RCBD) with four replications. The studied treatments were as follows:

1. Control treatment (without any treatment).
2. Treating paddy rice grains with phosphine at the rate of 2 tablets/ton.
3. Treating paddy rice grains with phosphine at the rate of 4 tablets/ton.
4. Treating paddy rice grains with phosphine at the rate of 6 tablets/ton.
5. Treating paddy rice grains with neem oil at the rate of 3%.
6. Treating paddy rice grains with neem oil at the rate of 6%.
7. Treating paddy rice grains with neem oil at the rate of 9%.

In all studied treatments, 3 kg of paddy rice grains in each replicate were stored in gunny package. The studied paddy rice Sakha 101 cultivar was obtained from the Experimental Farm of Sakha Agricultural Research Station, Kafrelsheikh Governorate, Agricultural Research Center (ARC), Egypt.

The phosphine insecticide (aluminium phosphide) and neem oil under study were produced by T. Stanes & Company Limited, India and obtained from Gaara Establishment for Import and Export Co.

Phosphine tablets which were used in the experiment were from an Indian origin and the rate of the active material was 57% like all other international origin. It is important to mention that the activity of phosphine tablets will take action when it is subject to air. In phosphine treatment, paddy rice has been put in plastic containers with sealing (drums) and then treated with various rates of phosphine for three days and then start of storage.

The neem oil was dissolved with acetone firstly, and then diluted with water to the studied rates. Paddy or milled rice grains were sprayed and well mixed with plant oils with various rates, and then beginning storage.

STUDIED CHARACTERS:

A- Storage efficacy characters:

After each storage period (2, 4 and 6 months from beginning storage), 1 kg of paddy rice of each treatment was taken to estimate the following characters:

1. Number of insects.

2. Insect infestation percentage.

Four replicates (100 grains) from each treatment were manually picked from different depth randomly for inspection. Grains which having holes or infestation were collected, also, the grain which showed signs of insect damage were considered. The infestation level was expressed as number and percentage damage grains according to formula of **Jood *et al.* (1996)**.

$$\text{Damage grains percent} = \frac{\text{Number of insect damage}}{\text{Number of total grains inspected}} \times 100$$

3. Grains weight loss percentage.

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: Nu = Number of undamaged grains.

Nd = Number of damaged grains.

U = Weight of undamaged grains.

D = Weight of damage grains.

B- Technological characters:

After each storage period (2, 4 and 6 months from beginning storage), 1 kg of paddy rice of each treatment was taken to estimate the following characters in Grain Quality Laboratory in Rice Research and Training Center, Sakha, Kafrelsheikh Governorate, Agricultural Research Center, Egypt:

1- Hulling percentage:

About 150 g cleaned rough rice samples at moisture content 12-14 % were estimated using experimental huller machine (satake) to determine hulling percentage as follows according to **Khush *et al.* (1979)**:

$$\text{Hulling (\%)} = \frac{\text{Brown rice weight}}{\text{Rough rice weight}} \times 100$$

2- Milling percentage:

The milled rice sample was then collected and the weight was taken and percentage of total milled rice was computed as follows according to **Ghosh *et al.* (1971)**:

$$\text{Milling (\%)} = \frac{\text{Milled rice weight}}{\text{Rough rice weight}} \times 100$$

3- Head rice (Grading) percentage:

Whole grains were separated from the total milled rice using a rice sizing device. The separation of these particles is termed as "grading". However, the broken are fragments of grains, which the lengths are less than 3/4 of the whole grains are after separated into two different sizes. The amount of head rice yield is then obtained and calculated (**IRRI, 1996**):

$$\text{Head rice (\%)} = \frac{\text{Head rice weight}}{\text{Rough rice weight}} \times 100$$

4- Amylose percentage: It was estimated according to **Juliano (1971)**.

5. Grain shape (%):

The shape of milled rice grain before cooking was determined by the length (L): width (W) ratio following the standard evaluation system for rice (**IRRI, 1996**).

6. Grain length after cooking (mm):

Grain length after cooking is a measure of milled rice grain in its greatest dimension in mm. It was measured from the base to the top of the grain. Grain length was classified using the Standard Evaluation System for rice **(IRRI 1996**).

7. Gelatinization temperature (GT) :

Six whole milled grains of rice from each treatment were spaced evenly in small transparent plastic boxes, containing 10 ml of potassium hydroxide solution 1.70%. The boxes are covered and left undisturbed for 23 hours in an incubator maintained at 30 ºC. Such alkali spreading and clearing of starchy endosperm represented the GT, which was visually rated on a 7-point numerical scale adopted by **Little *et al.* (1958).**

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the randomized complete block design (RCBD) as published by **Gomez and Gomez (1984)** by using means of “MSTAT-C” computer software package. New least significant of difference (NLSD) method was also used to test the differences between treatment means at 5% level of probability as described by **Waller and Duncan (1969)**.

Results and Discussion

1- Effect of storage periods:

Storage periods of paddy rice grains (2, 4 and 6 months) had a significant effect on storage efficacy characters (number of insects, insect infestation percentage and grains weight loss percentage) as shown in Table 1 and technological characters (hulling, milling, head rice "Grading", amylose, grain shape percentages, grain length after cooking and gelatinization temperature "GT") as shown in Table 3.

From obtained results in Tables 1 and 3, it could be noticed that the insects did not found in stored paddy rice grains after 2 months from beginning of storage, therefore paddy rice grains did not infested with insect and did not lost any weight after 2 months from beginning of storage.

The number of insects, insect infestation and paddy rice grains weight loss percentages as well as grain length after cooking and gelatinization temperature "GT" of paddy rice grains were significantly increased due to increasing storage periods from 2 to 4 and 6 months from beginning of storage over all studied grains treatment. However, hulling, milling, head rice "Grading", amylose and grain shape percentages were significantly decreased as a result of increasing storage periods of paddy rice grains from 2 to 4 and 6 months from beginning of storage over all studied grains treatment. These results may be owing to unsuitable conditions for storage, instability of the temperature and humidity during storage periods, moreover faded the effect of treating paddy rice grains with chemical insecticides (phosphine) or plant oils (oil neem) before storage.

2- Effect of paddy rice grains treatment:

The statistical analysis of obtained results showed that studied paddy rice grains treatment (untreated grains, treating with phosphine at the rates of 2, 4 and 6 balls/ton and oil neem at the rates of 3, 6 and 9%) had a significant effect on storage efficacy characters (number of insects, insect infestation percentage and grains weight loss percentage**)** as shown in Table 2 and technological characters (hulling, milling, head rice "Grading", amylose, grain shape percentages, grain length after cooking and gelatinization temperature "GT") as shown in Table 4 and over storage periods as shown in Table 1 and 3.

The lowest numbers of insects, insect infestation and grain weight loss percentages over storage periods were recorded in the samples of paddy rice grains treated with phosphine at the rates of 4 or 6 balls/ton, followed paddy rice grains treated with neem oil at the rate of 9 % (Table 2). On the other hand, the highest numbers of insects, insect infestation and grain weight loss percentages over storage periods have been recorded in the samples of paddy rice grains stored in gunny bags without any treatment.

Concerning technological characters *i.e.* hulling, milling, head rice "Grading", amylose, grain shape percentages, grain length after cooking and gelatinization temperature "GT", the highest of them was resulted from treating paddy rice grains before storage with phosphine at the rate of 6 balls/ton, followed treating with phosphine at the rate of 4 balls/ton, then treating with neem oil at the rate of 9 % and phosphine at the rate of 2 balls/ton (Table 4). Whereas, the lowest values of hulling, milling, head rice "Grading", amylose, grain shape percentages, grain length after cooking and gelatinization temperature "GT" produced from samples of paddy rice grains stored in gunny bags without any treatment.

The slight loss of paddy rice grains weight due to treating before beginning of storage with phosphine at the rate 6 balls/ton may be owing to phosphine gas had a slow-acting poison for different insect pests of stored products (**Collins et al., 2005**) which prevented the insects piercing and entering into grains and also the deleterious effect of phosphine on fungus development. In addition, phosphine is relatively easy to use, versatile, cheap, and accepted internationally as a low-residue treatment (**Collins et al., 2005**). The favourable effect of treating paddy rice grains before beginning of storage with neem oil at the rate 9% may be owing to neem seed oil had antifeedant effects for different insect pests of stored products, insect repellent action, prevented the insects piercing and entering into grains, increased insect growth inhibition and reduction of growth and sporulation of the fungi. In addition, the neem oil treatments did not show adverse effects on germination capability of seeds (**Kumawat and Bhanwar, 2013**). Therefore, extract of neem especially seed oil is considered as most effective botanical insecticide. Increasing grains weight loss percentages when storing paddy rice grains in gunny sacks without any treatment (control treatment) may be owing to appropriate conditions for the growth, establishment, development and spread of insects, and at the same time, absence of factors that limit the growth of insects.

Table 1: Number of insects, insect infestation percentage and grains weight loss percentage as affected by storage periods and treating paddy rice grains with phosphine insecticide and neem oil at various rates.

Characters / **Treatments**	**Number of insects**	**Insect infestation percentage (%)**	**Grains weight loss percentage (%)**
A- Storage periods:			
2 Months	0.00	0.00	0.00
4 Months	1.25	2.00	24.37
6 Months	5.07	3.57	30.84
F. test	*	*	*
NLSD at 5 %	0.56	0.44	2.93
B- Grains treatments:			
Untreated (control)	4.41	3.58	24.50
Phosphine at the rate of 2 balls/ton	2.00	2.33	20.35
Phosphine at the rate of 4 balls/ton	1.16	1.33	14.67
Phosphine at the rate of 6 balls/ton	1.25	0.91	12.51
Neem oil at the rate of 3 %	2.83	2.16	22.38
Neem oil at the rate of 6 %	1.91	1.75	21.10
Neem oil at the rate of 9 %	1.16	0.91	13.30
F. test	*	*	*
NLSD at 5 %	0.86	0.68	3.48
C- Interaction:	*	*	*

Table 2: Number of insects, insect infestation percentage and grains weight loss percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

Characters / Grains treatments	Number of insects			Insect infestation percentage (%)			Grains weight loss percentage (%)		
	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months
Untreated (control)	0.00	2.75	10.50	0.00	4.50	6.25	0.00	37.35	36.15
Phosphine at the rate of 2 balls/ton	0.00	1.75	4.25	0.00	2.75	4.25	0.00	30.27	30.80
Phosphine at the rate of 4 balls/ton	0.00	0.75	2.75	0.00	1.00	3.00	0.00	14.20	29.82
Phosphine at the rate of 6 balls/ton	0.00	0.50	3.25	0.00	0.75	2.00	0.00	11.55	26.00
Neem oil at the rate of 3 %	0.00	1.25	7.25	0.00	2.50	4.00	0.00	33.85	33.30
Neem oil at the rate of 6 %	0.00	1.25	4.50	0.00	1.75	3.50	0.00	31.60	31.72
Neem oil at the rate of 9 %	0.00	0.50	3.00	0.00	0.75	2.00	0.00	11.77	28.12
F. test	NS	*	*	NS	*	*	NS	*	*
NLSD at 5 %	-	0.70	1.70	-	1.33	1.23	-	2.28	1.88

3- Effect of the interaction between storage periods and grain treatments:

The interaction between storage periods and paddy rice grains treatments had a significant effect on number of insects, insect infestation percentage, grains weight loss percentage, hulling, milling, head rice "Grading", amylose percentages and grain length after cooking (Tables 1 and 3).

The lowest number of insects in paddy rice grains resulted from treating paddy rice grains with phosphine at the rate of 6 balls/ton or plant oil as neem oil at the rate of 9 % after 4 months of storage as graphically illustrated in Fig. 1. Whereas, the lowest number of insects in paddy rice grains produced from treating paddy rice grains with phosphine at the rate of 4 balls/ton after 6 months of storage.

Treating paddy rice grains with phosphine at the rate of 6 balls/ton or neem oil at the rate of 9 % recorded the lowest percentages of insect infestation and grains weight loss after 4 and 6 months from beginning storage as graphically illustrated in Figs. 2 and 3.

The highest values of hulling, milling, head rice "Grading", amylose percentages and grain length after cooking were resulted from treating with phosphine at the rate of 6 balls/ton after 2, 4 and 6 months of beginning storage, followed by treating with phosphine at the rate of 4 balls/ton, then treating with neem oil at the rate of 9 % after 2, 4 and 6 months of beginning storage as graphically illustrated in Figs. 4, 5, 6, 7 and 8.

Conclusion

This study recommended that treating paddy rice grains before storage with phosphine insecticide at the rate of 4 - 6 balls/ton or neem oil at the rate of 9 % to achieve the best possible storage efficacy and technological characters under the environmental conditions of the experiment in Mansoura, Dakahlia Governorate, Egypt.

Table 3: Hulling, milling, head rice (Grading), amylose, grain shape percentages, grain length after cooking and gelatinization temperature (GT) as affected by storage periods and treating paddy rice grains with phosphine insecticide and neem oil at various rates.

Treatments / Characters	Hulling (%)	Milling (%)	Head rice (%)	Amylose (%)	Grain shape (%)	Grain length after cooking (mm)	GT
A- Storage periods:							
2 Months	81.91	72.05	64.35	19.51	2.36	7.01	5.00
4 Months	80.69	71.16	63.67	19.49	2.26	8.24	5.53
6 Months	79.86	70.04	62.58	19.00	1.98	8.44	6.10
F. test	*	*	*	*	*	*	*
NLSD at 5 %	0.08	0.06	0.05	0.03	0.04	0.02	0.25
B- Grains treatments:							
Untreated (control)	79.22	69.83	62.12	18.93	2.18	7.50	4.66
Phosphine at the rate of 2 balls/ton	81.06	71.25	63.56	19.35	2.19	7.90	5.58
Phosphine at the rate of 4 balls/ton	81.90	71.71	64.63	19.53	2.21	8.14	6.00
Phosphine at the rate of 6 balls/ton	82.60	72.08	64.88	19.72	2.27	8.24	6.33
Neem oil at the rate of 3 %	79.57	70.45	62.39	19.14	2.18	7.69	5.08
Neem oil at the rate of 6 %	80.06	70.76	63.18	19.24	2.18	7.82	5.50
Neem oil at the rate of 9 %	81.33	71.53	63.98	19.43	2.19	7.99	5.66
F. test	*	*	*	*	*	*	*
NLSD at 5 %	0.12	0.09	0.08	0.05	0.06	0.03	0.38
C- Interaction:	*	*	*	*	NS	*	NS

Table 4: Hulling, milling, head rice (Grading), amylose, grain shape percentages, grain length after cooking and gelatinization temperature (GT) as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

Characters / Grains treatments	Hulling (%)			Milling (%)			Head rice (%)			Amylose (%)			Grain shape (%)			Grain length after cooking (mm)			GT		
	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months	2 Months	4 Months	6 Months
Untreated (control)	**81.16**	**78.41**	**78.09**	**71.30**	**69.99**	**68.20**	**63.15**	**62.11**	**61.10**	**19.03**	**19.12**	**18.66**	2.31	2.19	1.96	6.48	8.05	7.98	4.50	4.75	4.75
Phosphine at the rate of 2 balls/ton	**81.90**	**81.15**	**80.13**	**72.13**	**71.34**	**70.30**	**64.20**	**63.89**	**62.60**	**19.55**	**19.50**	**19.00**	2.35	2.23	1.98	7.05	8.21	8.43	5.00	5.50	6.25
Phosphine at the rate of 4 balls/ton	**82.41**	**82.10**	**81.20**	**72.50**	**71.93**	**70.70**	**65.20**	**64.93**	**63.77**	**19.70**	**19.62**	**19.28**	2.38	2.29	1.99	7.32	8.38	8.72	5.50	5.75	6.75
Phosphine at the rate of 6 balls/ton	**82.75**	**82.92**	**82.15**	**73.18**	**72.22**	**70.84**	**65.63**	**65.07**	**63.94**	**19.97**	**19.88**	**19.32**	2.47	2.39	2.01	7.38	8.40	8.95	5.50	6.50	7.00
Neem oil at the rate of 3 %	**81.30**	**79.20**	**78.22**	**71.40**	**70.19**	**69.75**	**63.40**	**62.57**	**61.20**	**19.31**	**19.31**	**18.80**	2.33	2.22	1.97	6.83	8.13	8.13	4.50	5.00	5.75
Neem oil at the rate of 6 %	**81.77**	**79.80**	**78.62**	**71.50**	**70.83**	**69.97**	**64.13**	**63.10**	**62.30**	**19.36**	**19.45**	**18.91**	2.33	2.22	1.97	6.93	8.16	8.38	5.00	5.50	6.00
Neem oil at the rate of 9 %	**82.13**	**81.24**	**80.63**	**72.39**	**71.65**	**70.54**	**64.74**	**64.01**	**63.20**	**19.64**	**19.57**	**19.08**	2.38	2.28	1.98	7.11	8.35	8.52	5.00	5.75	6.25
F. test	*	*	*	*	*	*	*	*	*	*	*	*	*	NS	NS	*	*	*	*	*	*
NLSD at 5 %	0.10	0.22	0.24	0.11	0.19	0.15	0.12	0.23	0.13	0.07	0.08	0.06	0.03	-	-	0.06	0.05	0.05	0.62	0.74	0.78

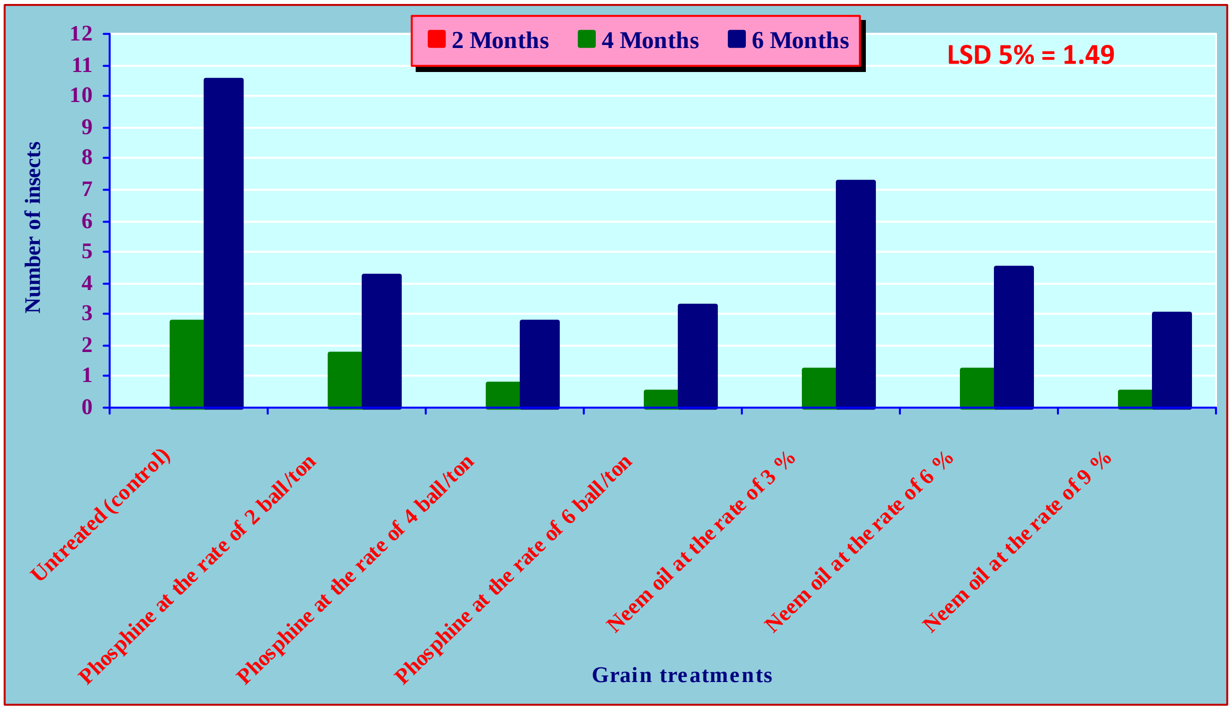

Fig. 1: Number of insects as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

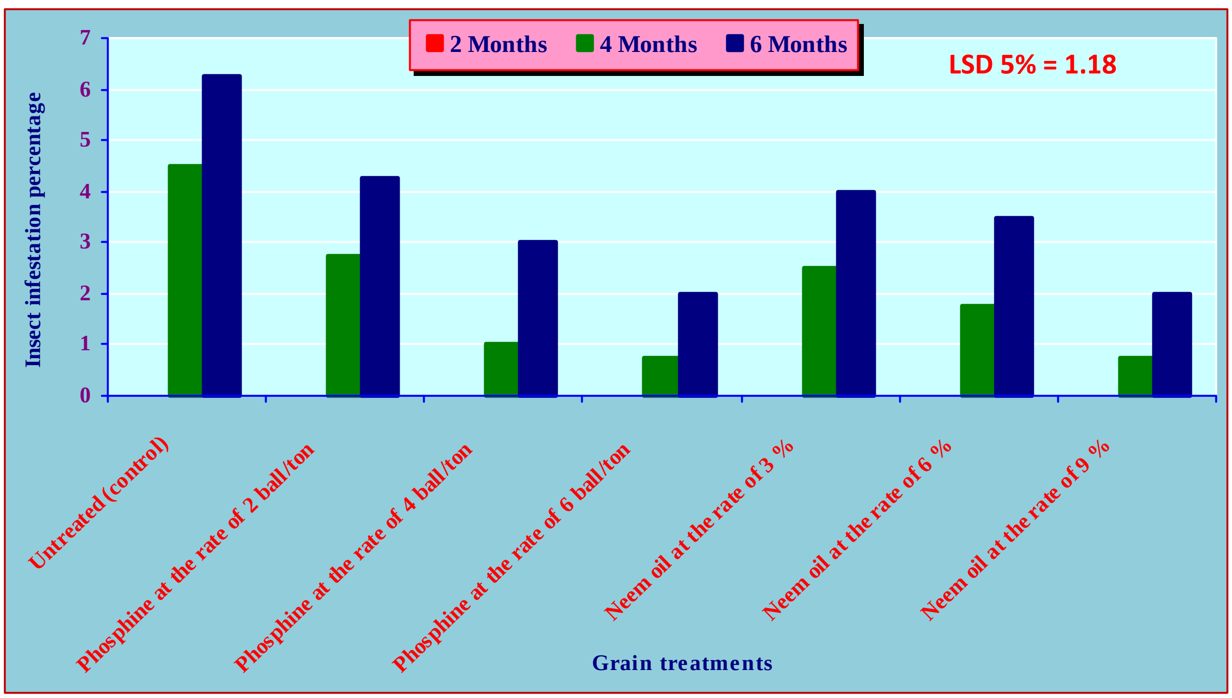

Fig. 2: Insect infestation percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

Fig. 3: Grains weight loss percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

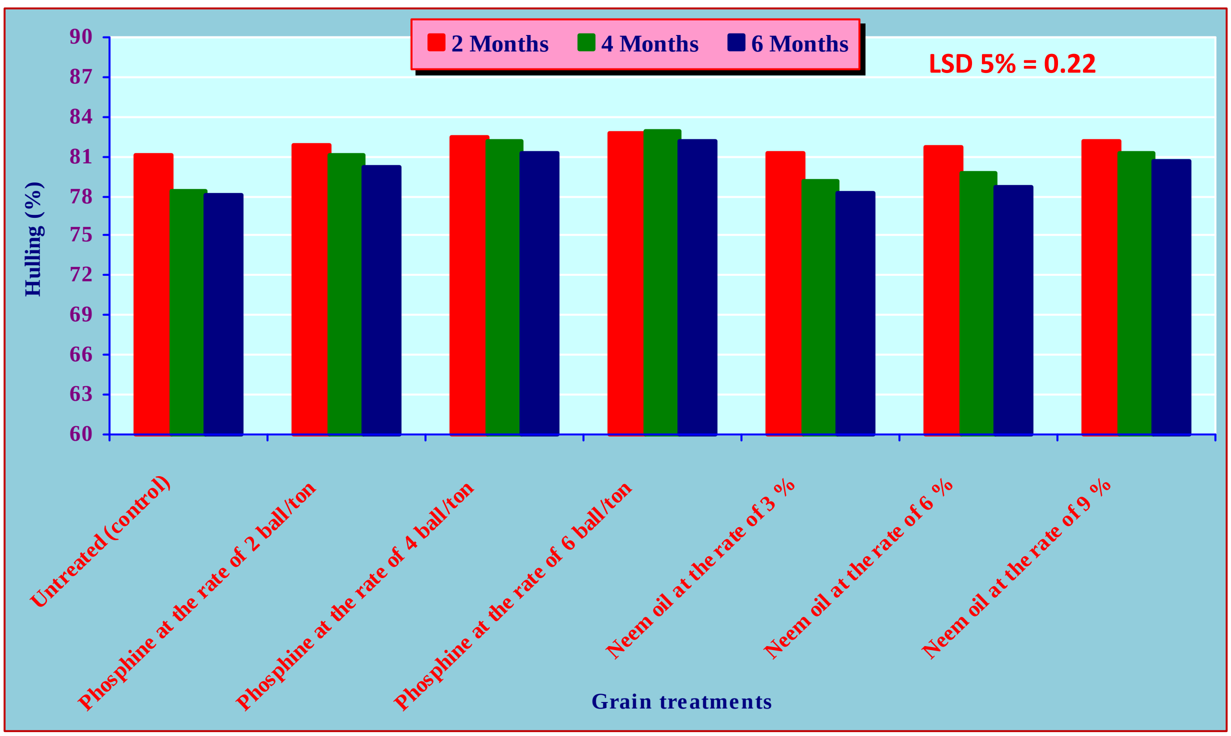

Fig. 4: Hulling percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

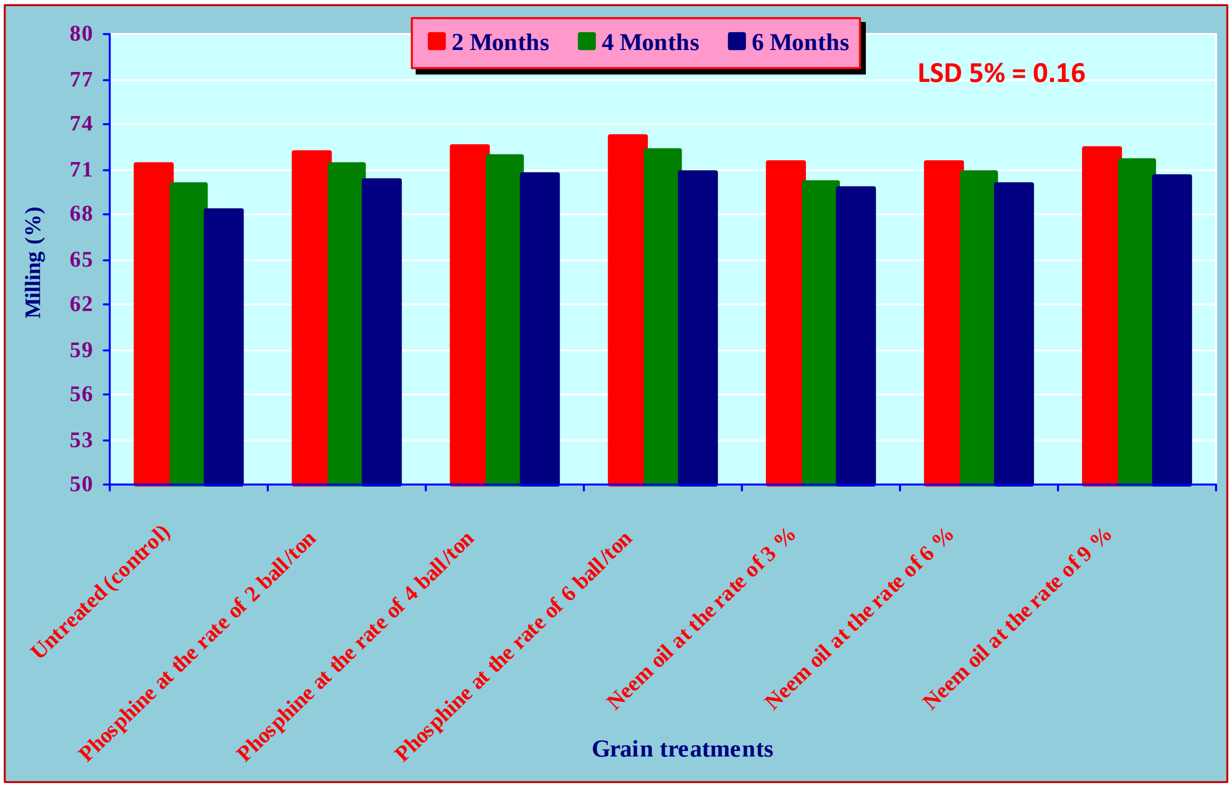

Fig. 5: Milling percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

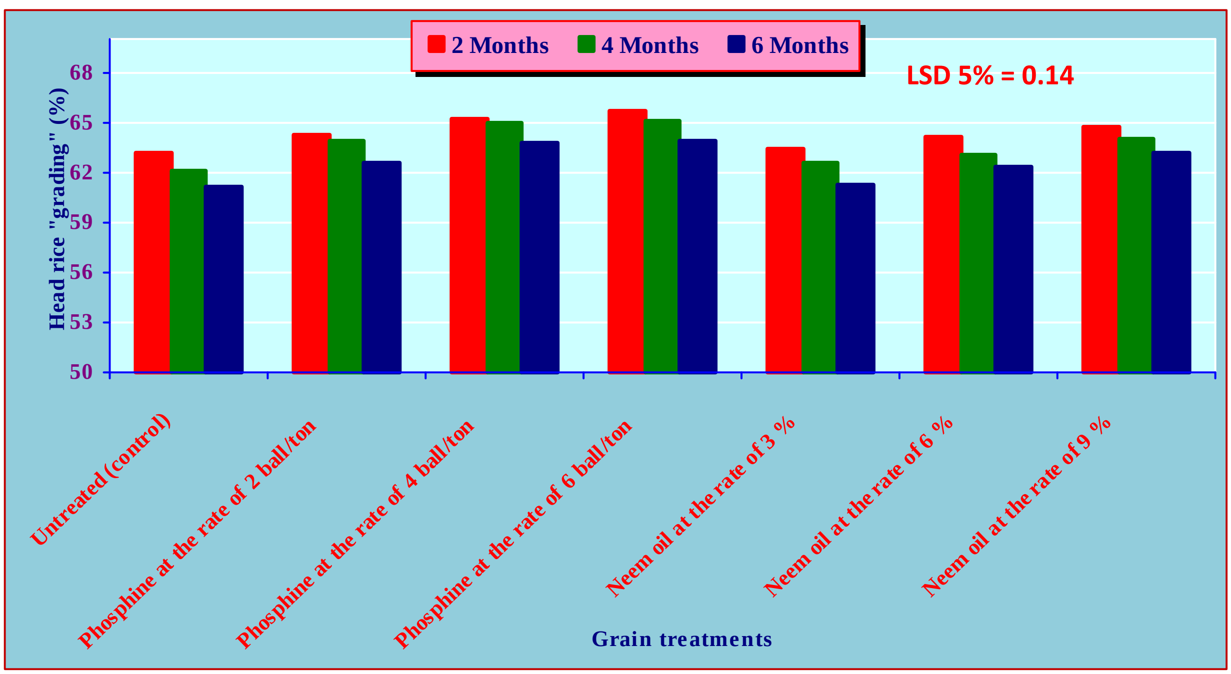

Fig. 6: Head rice (grading) percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

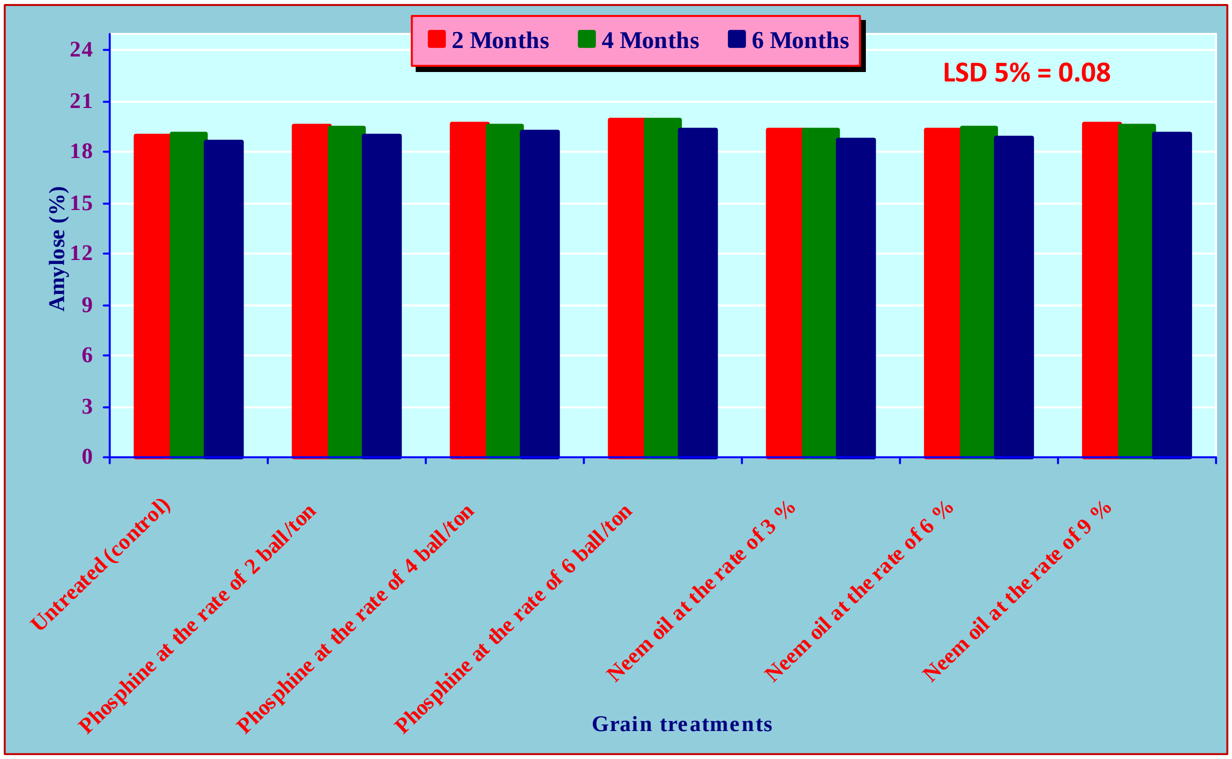

Fig. 7: Amylose percentage as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

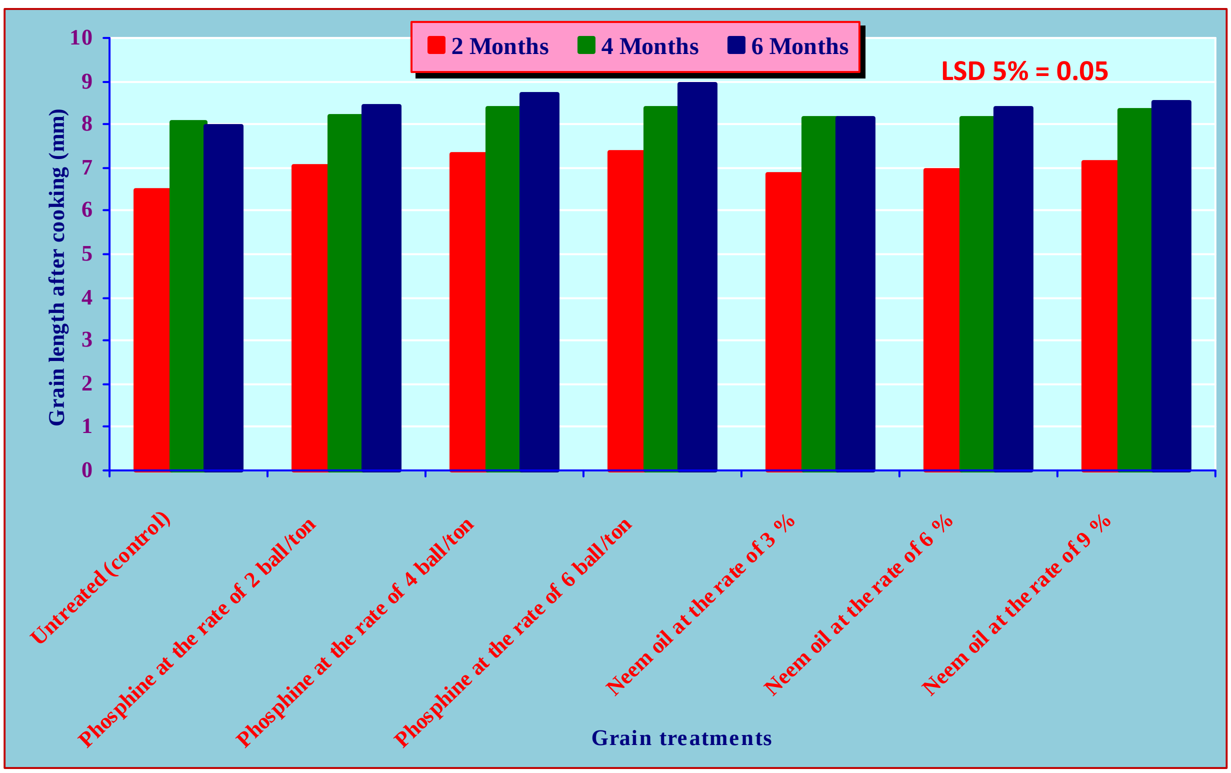

Fig. 8: Grain length after cooking (mm) as affected by treating paddy rice grains with phosphine insecticide and neem oil at various rates after 2, 4 and 6 months of storage.

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