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EFFECT OF OIL IMPREGNATED BAGS ON *TROGODERMA GRANARIUM EVERTS* (COLEOPTERA: DERMESTIDAE) IN TERMS OF POPULATION BUILD-UP AND GRAIN DAMAGE

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ABSTRACT
Trogoderma granarium Everts is a serious pest of stored grains and having a status of a dangerous quarantine pest for most of the countries important from Indian export point of view. Its detection attracts serious economic and trade restrictions. It is presently controllable only by methyl bromide (CH_3Br), which is facing a blanket ban in many countries due to its ozone depleting nature. Hence an alternate management strategy is envisaged by using eco-friendly, economic, effective, non-hazardous, easily available and easy to use material. A part of this IPM protocol begins with a minimal-invasive technique by exploiting the inherent effects of commonly used bags by modifying the microenvironment of the storages by impregnating the bags with repellent oils. Present paper describes the comparative efficacy of oil impregnated bags in containing this pest.

Key words: *Trogoderma granarium*, IPM, minimal-invasive technique, Ozone depletion, Storage grains, impregnation.

INTRODUCTION

The Khapra beetle, *Trogoderma granarium* Everts is one of the most notorious primary insect pests of stored grains (Banks, 1977; Hill, 1983). It causes direct and various indirect losses consequently leading to deterioration of grain characteristics (El Nadi *et al*., 2001). It is a serious pest under hot dry conditions. In fact, it has been recognized as an A2 quarantine organism for EPPO (OEPP/EPPO, 1981) and ranked as one of the 100 worst invasive species worldwide (Lowe *et al*., 2000). The status of Khapra beetle is of highly economic importance due to its continued occurrence on commodities imported from countries where it is indigenous, and the potential for spread due to increasing use of dry cargo containers and roll-on roll-off road transport, make it a potential threat to the global food security. If infestation is severe, the devastation is complete, reducing the grain to mere frass (EPPO, 1990). Its exuviae, shed skin and other body parts are carcinogenic to human beings. It is a polyphagous and most feared upon pest, from quarantine point of view, especially in western countries that are of strategic importance to India for exports of cereals, pulses, oilseeds, etc. The presence of this pest attracts trade restriction implications. Non-Khapra beetle countries enforce quarantine restrictions on the imported commodities from Khapra beetle countries. The US Government spent about $15 million for its eradication programme, when it was accidentally introduced into USA (Kerr, 1981). In India, a number of export shipments have suffered heavy losses owing to detection of this pest in one or other form. Recently Russia banned imports of plant products from India owing to detection of this pest in a consignment of sesame (Reuters, 2006, HT Media, 2007). Protection of stored grains from insect damage is currently dependent on various control measures mainly on synthetic pesticides such as fumigation with phosphine or methyl bromide or dusting with compounds like primiphos-methyl and permethrin (Price and Mills, 1988; Singh, 1990). The wide spread use of such chemicals has significant drawbacks i.e., development of strains resistant to pesticides (Zettler and Cuperus, 1990), increased costs, handling hazards, insecticide residues on grains and great threat to environment and human health. Outbreaks of environmental hazards related to contribution of fumigants such as methyl bromide on the degradation of stratospheric ozone (Taylor, 1994; Noling and Becker, 1994) initiated calls to phase out methyl bromide usage. A study conducted under laboratory conditions was planned to develop an alternate management protocol in the scheme of IPM, which would be nature friendly, effective, economical, safe, sustainable and easy to apply, for the control of the important primary insect pest of stored grains, *i. e*. Khapra beetle. The various materials evaluated are farmer friendly and do not demands an access to sophisticated control methods and / or costly equipments. A part of the study made dealt with the impregnation of commonly used jute bags and white cotton cloth bags with three repellent oils to explore the effect of oil impregnated bags; the details of which are presented in this paper.

MATERIALS & METHODS

The insects were maintained in round glass jars of 1 Kg capacity, half filled with whole wheat grains and their mouths covered with double folded muslin cloth held tight with the help of 4″ rubber bands around its neck. The wheat was properly dried, cleaned and conditioned. The culture was allowed to breed for three generations. The controlled conditions maintained in the laboratory were 27±1˚C temperature, 65±5 % relative humidity and 12 h photoperiod.

White cotton-cloth bags and commonly used jute bags were impregnated with 5% (v/v) neem, pongamia and mustard oil. The bags were thoroughly drenched by spraying on both the surfaces. The required quantity of the oil was dissolved in acetone solvent and the dilution thus prepared was sprayed thoroughly with the help of a hand sprayer on the jute and cloth bags specially prepared to hold 500 gram wheat capacity. After spraying, the bags were dried under the ceiling fan and then filled with 500 gram conditioned wheat grains. Five pairs of adults were released in each of these bags and then the bags were sewed with thread (Fig.1**)**.The observations were taken at the end of 3, 6 and 9 months. Observations were taken to determine the trend of population growth of Khapra beetle by making the interactions of bag types *vs*. impregnating oils. All the experiments were carried out in triplicates. This experiment aimed at assessing the efficacy of oil impregnated bag type in containing the population growth of the Khapra beetle.

FIGURE 1. Oil impregnated bags of jute and cotton cloth

RESULTS

Population build-up studies

Grubs

At the end of three month – period; it was observed that cotton cloth was found superior over jute when bag structure is considered. The bag impregnation experiments showed that the number of grubs present was 89.33, 89.33 and 80 in Cotton Cloth Bags and 218, 211 and 203 in Jute bags (both) impregnated with Mustard oil, Neem Oil and Pongamia Oil respectively. All treatments were superior to Control, where the number of grubs recorded at this stage was 511. 33 and 618.33 in Cotton and Jute bags respectively. The observations recorded at the end of six and nine months exhibited the similar trend though the population increased further in varying manner.

Adults

At the end of three months; numbers of adults were more or less same in all treatments in case of cotton cloth bags, i.e. 18.67, 19.67 and 17 in Mustard, Neem and Pongamia oils respectively. Average number of adults in Cotton cloth bag was found to be 18.45. However in jute bags no adult stages were seen irrespective of the impregnating oil used.

At the end of six months; Cotton cloth was found superior over jute cloth in all cases. The impregnated bags, in order of effectiveness, were Pongamia oil impregnated bag > Neem oil impregnated bag > Mustard oil impregnated bag.

At the end of nine months; the population curve of adults traversed similar path to the one in 6-month storage period. All treatments were superior to Control (Table 1).

Grain Damage studies

Percentage of grain damage was significantly more in case of jute bags. Mustard, Neem and Pongamia oils recorded the respective damage levels of 1.0, 1.0, 0.987 in case of cotton cloth bag and 2.0, 1.96 and 1.9 in Jute bags respectively. All treatments were superior to Control in which the percent damage of grain was 5.053 and 6.267 in Cotton cloth and Jute bags respectively. At the end of six and nine month-periods; the damage levels further increased in all cases but the trend of increase was similar to that of 3-month period. The detailed account of the results obtained are tabulated, statistically processed and presented in Table 2, 3 & 4. Their graphical representation is depicted in Figure 2 and 3 . Thus, the observations in general indicate that, when bag structure is considered, cotton cloth was found superior over jute. All the oils were effective against *Trogoderma* build-up when compared with Controls and all treatments were superior to Control. The larval count increased further with storage time in all of the treated bags. Numbers of adults were more or less same in all of the treatments in case of cotton cloth bags at the end of three months and then increased with time. In case of Jute bags, however, no adult stages were seen irrespective of the impregnating oil used. Percentage of grain damage was significantly more in case of jute bags. The statistical analyses indicate that the various treatments and their interactions were significant to highly significant.

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TABLE 1: Effect of oil impregnated bags on population build-up of *Trogoderma granarium* Everts (with 5 pairs of adult insects)

Storage structure/ Parameter		Number of grubs			Number of adults			Grain damage (%)		
		After 3 months	After 6 months	After 9 months	After 3 months	After 6 months	After 9 months	After 3 months	After 6 months	After 9 months
Type of Bag	Impregnating Oil									
Cotton Cloth Bag	- Mustard oil	89.33	480.33	628.33	18.67	48.33	095.00	1.000	03.40	09.91
	- Neem oil	89.33	489.67	615.67	19.67	52.67	093.33	1.000	03.70	09.03
	- Pongamia oil	80.00	451.67	508.00	17.00	37.33	67.67	0.907	03.10	09.00
	- Control	511.33	844.33	0997.00	212.33	556.33	1079.00	5.053	13.733	21.107
Jute Bag	- Mustard oil	218	614.33	749.33	0	72.33	431.66	2.00	4.12	11.16
	- Neem oil	211	630.00	723.67	0	76.33	427.33	1.96	4.23	10.06
	- Pongamia oil	203	611.33	676.67	0	48.67	400.00	1.90	4.07	09.70
	- Control	618.33	1072.33	1207.00	222.67	666.33	1400.67	6.267	15.633	36.000

Statistical Analysis

TABLE 2: Number of grubs

Descriptives

No of larvae

	N	Mean	Std. Deviation	Std. Error
3.00	8	252.3750	203.18741	71.83760
6.00	8	749.1250	386.71416	136.72410
9.00	8	1133.2500	957.38211	338.48569
Total	24	711.5833	687.54667	140.34488

ANOVA

No of larvae

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3120676	2	1560337.792	4.227	.029
Within Groups	7751894	21	369137.821		
Total	10872570	23			

Post Hoc Tests-

Multiple Comparisons

Dependent Variable: No of larvae

LSD

(I) month	(J) month	Mean Difference (I-J)		Std. Error	Sig.
3.00	6.00	-496.75000		303.78357	.117
	9.00	-880.87500	*	303.78357	.009
6.00	3.00	496.75000		303.78357	.117
	9.00	-384.12500		303.78357	.220
9.00	3.00	880.87500	*	303.78357	.009
	6.00	384.12500		303.78357	.220

*. The mean difference is significant at the .05 level.

ANOVA

No of larvae

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	324337.5	1	324337.500	.676	.420
Within Groups	10548232	22	479465.106		
Total	10872570	23			

Descriptives

No of larvae

	N	Mean	Std. Deviation	Std. Error
Cotton cloth bag	12	595.3333	532.09660	153.60306
Jute bag	12	827.8333	822.07264	237.31193
Total	24	711.5833	687.54667	140.34488

Descriptives

No of larvae

	N	Mean	Std. Deviation	Std. Error
Mustard oil	6	463.0000	257.68663	105.20013
Neem oil	6	460.0000	254.35172	103.83866
Pongamia oil	6	421.8333	234.07983	95.56269
Control	6	1501.5000	994.48977	405.99875
Total	24	711.5833	687.54667	140.34488

ANOVA

No of larvae

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4998068	3	1666022.500	5.672	.006
Within Groups	5874502	20	293725.117		
Total	10872570	23			

Post Hoc Tests-

Multiple Comparisons

Dependent Variable: No of larvae

LSD

(I) impregnation	(J) impregnation	Mean Difference (I-J)	Std. Error	Sig.
Mustard oil	Neem oil	3.00000	312.90314	.992
	Pongamia oil	41.16667	312.90314	.897
	Control	-1038.5000*	312.90314	.003
Neem oil	Mustard oil	-3.00000	312.90314	.992
	Pongamia oil	38.16667	312.90314	.904
	Control	-1041.5000*	312.90314	.003
Pongamia oil	Mustard oil	-41.16667	312.90314	.897
	Neem oil	-38.16667	312.90314	.904
	Control	-1079.6667*	312.90314	.003
Control	Mustard oil	1038.50000*	312.90314	.003
	Neem oil	1041.50000*	312.90314	.003
	Pongamia oil	1079.66667*	312.90314	.003

*. The mean difference is significant at the .05 level.

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TABLE 3: Number of adults

Description				
No. of Adults				
	N	Mean	Std. Deviation	Std. error
3.00	8	61.3750	96.79719	34.22298
6.00	8	188.6250	263.25324	93.07408
9.00	8	499.3750	490.37739	173.37459
Total	24	249.7917	363.93179	74.28727

ANOVA					
No. of Adults					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	812272.3	2	406136.167	3.818	.039
Within Groups	2233994	21	106380.649		
Total	3046266	23			

Post Hoc Tests-

Multiple Comparisons

Dependent Variable: No of adults

LSD

(I) month	(J) month	Mean Difference (I-J)	Std. Error	Sig.
3.00	6.00	-127.25000	163.08023	.444
	9.00	-438.00000 *	163.08023	.014
6.00	3.00	127.25000	163.08023	.444
	9.00	-310.75000	163.08023	.070
9.00	3.00	438.00000 *	163.08023	.014
	6.00	310.75000	163.08023	.070

*. The mean difference is significant at the .05 level.

ANOVA

No of adults

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	93375.375	1	93375.375	.696	.413
Within Groups	2952891	22	134222.299		
Total	3046266	23			

ANOVA

No of adults

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1547500	3	515833.375	6.883	.002
Within Groups	1498766	20	74938.292		
Total	3046266	23			

Descriptives

No of adults

	N	Mean	Std. Deviation	Std. Error
Mustard oil	6	111.0000	160.97950	65.71961
Neem oil	6	103.5000	163.03711	66.55962
Pongamia oil	6	95.1667	151.22357	61.73676
Control	6	689.5000	473.69727	193.38610
Total	24	249.7917	363.93179	74.28727

Multiple Comparisons

Dependent Variable: No of adults

LSD

(I) impregnation	(J) impregnation	Mean Difference (I-J)	Std. Error	Sig.
Mustard oil	Neem oil	7.50000	158.04882	.963
	Pongamia oil	15.83333	158.04882	.921
	Control	-578.50000 *	158.04882	.002
Neem oil	Mustard oil	-7.50000	158.04882	.963
	Pongamia oil	8.33333	158.04882	.958
	Control	-586.00000 *	158.04882	.001
Pongamia oil	Mustard oil	-15.83333	158.04882	.921
	Neem oil	-8.33333	158.04882	.958
	Control	-594.33333 *	158.04882	.001
Control	Mustard oil	578.50000 *	158.04882	.002
	Neem oil	586.00000 *	158.04882	.001
	Pongamia oil	594.33333 *	158.04882	.001

*. The mean difference is significant at the .05 level.

TABLE 4: Grain Damage

Descriptives

No. of Kernels damaged (in 1000 kernels)

	N	Mean	Std. Deviation	Std. Error
3.00	8	25.2500	20.39433	7.21048
6.00	8	64.8750	50.77524	17.95176
9.00	8	113.6250	121.45068	42.93930
Total	24	67.9167	82.24085	16.78734

ANOVA

No. of Kernels damaged (in 1000 kernels)

	Sum of Squares	df	Mean Squar	F	Sig.
Between Group	31351.58	2	15675.79	2.650	.094
Within Groups	124210.	21	5914.77		
Total	155561.	23			

Post Hoc Tests-

Multiple Comparisons

Dependent Variable: No. of Kernels damaged (in 1000 kernels)

LSD

(I) month	(J) month	Mean Difference (I-J)	Std. Error	Sig.
3.00	6.00	-39.62500	38.45378	.315
	9.00	-88.37500 *	38.45378	.032
6.00	3.00	39.62500	38.45378	.315
	9.00	-48.75000	38.45378	.219
9.00	3.00	88.37500 *	38.45378	.032
	6.00	48.75000	38.45378	.219

*. The mean difference is significant at the .05 level.

Descriptives

No. of Kernels damaged (in 1000 kernels)

	N	Mean	Std. Deviation	Std. Error
Cotton cloth bag	12	46.5000	63.22615	18.25182
Jute bag	12	89.3333	95.62268	27.60389
Total	24	67.9167	82.24085	16.78734

Descriptives

No. of Kernels damaged (in 1000 kernels)

	N	Mean	Std. Deviation	Std. Error
Mustard oil	6	37.8333	38.45213	15.69802
Neem oil	6	36.5000	34.41366	14.04932
Pongamia oil	6	34.3333	33.17027	13.54171
Control	6	163.0000	113.47423	46.32566
Total	24	67.9167	82.24085	16.78734

Post Hoc Tests-

ANOVA

No. of Kernels damaged (in 1000 kernels)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11008.167	1	11008.167	1.675	.209
Within Groups	144553.7	22	6570.621		
Total	155561.8	23			

ANOVA

No. of Kernels damaged (in 1000 kernels)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	72364.167	3	24121.389	5.799	.005
Within Groups	83197.667	20	4159.883		
Total	155561.8	23			

Post Hoc Tests-

Multiple Comparisons

Dependent Variable: No. of Kernels damaged (in 1000 kernels)
LSD

(I) impregnation	(J) impregnation	Mean Difference (I-J)		Std. Error	Sig.
Mustard oil	Neem oil	1.33333		37.23745	.972
	Pongamia oil	3.50000		37.23745	.926
	Control	-125.16667	*	37.23745	.003
Neem oil	Mustard oil	-1.33333		37.23745	.972
	Pongamia oil	2.16667		37.23745	.954
	Control	-126.50000	*	37.23745	.003
Pongamia oil	Mustard oil	-3.50000		37.23745	.926
	Neem oil	-2.16667		37.23745	.954
	Control	-128.66667	*	37.23745	.003
Control	Mustard oil	125.16667	*	37.23745	.003
	Neem oil	126.50000	*	37.23745	.003
	Pongamia oil	128.66667	*	37.23745	.003

*. The mean difference is significant at the .05 level.

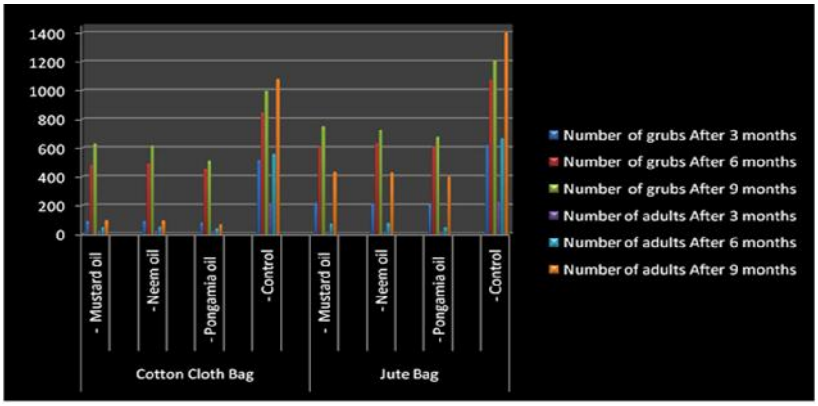

FIGURE 2. Effect of oil impregnated bags on population build-up of *Trogoderma granarium* Evert

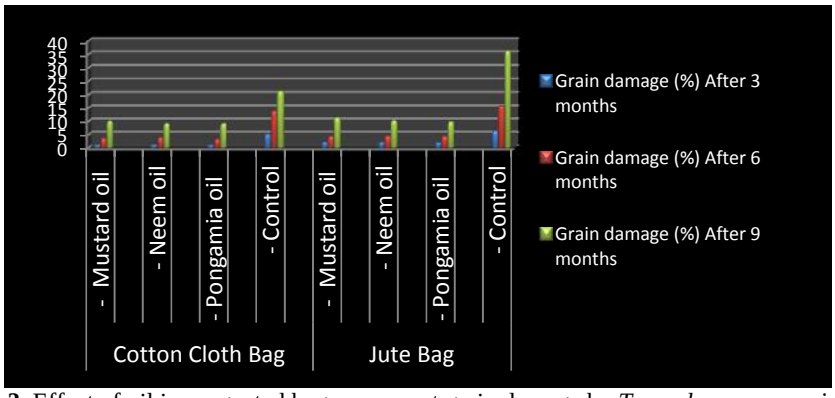

FIGURE 3. Effect of oil impregnated bag on percent grain damage by *Trogoderma granarium* Everts

DISCUSSIONS

Cotton cloth bags were found superior over jute bags. The impregnating oils did not differ much in their efficacy but all of them were superior to the Controls. The population build-up increased with time. The grain damage was directly proportional to the population build-up and to the passage of time. Thus, some protection was offered at all-time stages *i.e.* three, six and nine months as compared to Controls and the impregnation of the bags is useful in excluding and / or repelling the insects. Present

investigations reveal that the closeness of the weave of bagging material is indeed important as shown in case of Jute bags. The adults escaped the impregnated jute bags probably after egg laying. At the end of three months practically no live adult was seen in jute bags irrespective of the impregnating oil. In case of cotton cloth bags they could not escape due to its close weave. Parkin (1948) reported, while experimenting with DDT impregnation of sacks, that if the treated material is of sufficiently close weave, it affords some mechanical hindrance to penetration by insects. Meena and Bhargava (2009) reported that bag drenching with neem and mustard oils in gunny and cotton bags offered protection from *Corcyra cephalonica* upto two months. Cotton bags were found superior to gunny bags. Anwar *et al.* (2005) tried neem oil with different concentrations at the intervals of 30, 60 and 90 days on packaging materials of two different densities. Significant changes were observed due to type of packaging material. Deterrence to penetration decreased with passage of time. It is concluded that the impregnating the bags with repellent oils is effective. Cotton-cloth bags are recommended over jute bags. The jute bags can also be used for storage but only if impregnated with repellent oils and if the produce is planned for short-time storage *i.e.* for less than three months.

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