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

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Original Article

ABSTRACT

Trogoderma granarium Everts has posed serious threat to global food security and safety. It causes huge loss in 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.The various control measures such as physical, chemical, mechanical controls are being implemented to control them.It is presently controlled by fumigation of methyl bromide (CH_3Br), aluminium phosphate (ALP tablets) and other conventional insecticides, 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, effective, economical, 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 using the modified storage structures. The present research focussed on the effect of storage structures on Trogoderma granarium Everts in terms of the population build-up and the grain damage.

KEYWORDS: Trogoderma garanarium, IPM, Quarantine, Invasive, Fumigation, Eco-Friendly

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INTRODUCTION

The Khapra beetle, *Trogoderma granarium* Everts is one of the most notorious primary insect pests of stored grains products (Banks, 1977; Hill, 1983). It causes direct and various indirect losses consequently leading to deterioration of grain characteristics (El Nadi et al., 2001). Losses caused by this pest have been reported to range from 0.2 to 2.9% over a period of 1 to 10.5 months (Irshad and Iqbal, 1994). It is a very serious pest under hot and dry conditions. 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, especially in western countries that are of strategic importance to India for exports of cereals, pulses, oilseeds, etc. 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 synthetic pesticides such as fumigation with phosphine, methyl bromide or dusting with compounds like primiphos-methyl and permethrin (Price and Mills, 1988; Singh, 1990). Synthetic insecticides provide protection from insect pests but also associated with residual effects and their widespread use has led to some serious problems, including development of insect strains resistant to insecticides (Su, 1991), toxic residues on stored grain , health hazards to grain handler, increased costs 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 approach in the scheme of Integrated Pest Management, which would be eco- 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, *Trogoderma granarium* Everts. 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 use of proper packaging material to explore the penetrative / invading capabilities of this beetle; the details of which are presented in this paper.

MATERIALS AND METHODS

The insect pests 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.

Various types of bags *i.e.* Jute, White cotton-cloth, Synthetic cloth, Black cotton-cloth and HDPE, were specially sewed so as to hold the grains of 500 grams capacity. Plastic bags of 100, 200 and 400 gauge and mud pots of 500 gram capacity each were obtained from the market (Figure 1). 500 grams of conditioned wheat grains were filled in each of the containers and five pairs of adults were released in each of them. Jute, white cotton- cloth, synthetic cloth, black cotton-cloth and HDPE bags were sewed with thread. Mud pots were closed with double folded muslin cloth held tight with 4" rubber bands. Plastic bags of 100, 200 and 400 gauge were sealed. Three replicates were maintained. Proper labeling was done. Observations were made at every 3rd month *i.e.*, after 3 months, 6 months and 9 months to see the population growth of the test insect in each of these containers. An actual count of the number of adults and number of larvae were taken. The grain damage was also recorded in each of these containers. This experiment was aimed to determine whether any particular type of containers prove to be an ideal one, from among those used in the study.

100 Gauge Plastic Bag **200 Gauge Plastic Bag** **400 Gauge Plastic Bag**



White Cotton-Cloth Bag Black Cotton-Cloth Bag Jute Bag



HDPE Bag Mud Pot Synthetic Cloth Bag

Figure 1: Various Types of Bags

The container types selected were of such common material that are easily available in the market and are affordable ones.

RESULTS

The results obtained in this experiment are presented in the following Table 1 along with statistical analysis (Table 2).

Table 1: Effect of Storage Structures on Population Buildup of *Trogoderma granarium* Everts and on Grain Damage

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
White cotton-cloth bag	511.33	1244.33	1957.00	212.330	556.33	1079.00	5.053	13.733	21.107
Jute bag	618.33	1472.33	3207.00	222.670	666.33	1400.67	6.267	15.633	36.000
Synthetic cloth bag	420.67	843.33	1858.67	120.670	557.33	0973.67	4.633	08.400	19.100
Black cotton-cloth bag	542.33	1144.33	1844.33	232.330	587.67	1117.67	5.300	14.333	22.887
HDPE bag	422.33	867.67	1839.00	119.670	567.00	0988.33	4.700	08.500	20.033
Mud pot	749.00	2996.67	9363.67	329.000	952.67	2343.00	8.080	37.440	99.320
Plastic 100 gauge bag	0	---	---	0	---	---	1.500	---	---
Plastic 200 gauge bag	0	---	---	0	---	---	1.100	---	---
Plastic 400 gauge bag	0	---	---	0	---	---	0.020	---	---

*The observations in sealed plastic bags of 100, 200 and 400 gauge were deferred after 3 months as they as they showed 100% kill in the first three months itself.

Figure 2: Grain Damage in Mud Pot after 9 Months Period

Table 2: Statistical Analysis

Oneway-
Descriptives- No. of grubs

	N	Mean	Std.Deviation	Std.Error
3.00	9	362.5566	289.42102	96.47367
6.00	9	952.0000	956.05975	318.68658
9.00	9	2452.2222	3524.42881	1174.810
Total	27	1255.5926	2220.96445	427.42481

ANOVA
No. of grubs

	Sum of squares	df	Mean square	F	Sig.
Between groups	20894455	2	10447227.37	2.336	.118
Within groups	1E+008	24	4431 37.741		
Total	1E+008	26			

Post Hoc Tests- Multiple Comparisons-
Dependent Variable:No.of grubs- LSD

(I)Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.
3.00	6.00	-589.44444	997.01084	.560
	9.00	-2089.6667*	997.01084	.047
6.00	3.00	589.44444	997.01084	.560
	9.00	-1500.2222	997.01084	.145
9.00	3.00	2089.66667*	997.01084	.047
	6.00	1500.22222	997.01084	.145

*The mean difference is significant at the .05 level

Oneway-
Descriptives- No. of adults

	N	Mean	Std.Deviation	Std.Error
3.00	9	137.4444	120.29143	40.09714
6.00	9	431.8889	346.8889	115.44785
9.00	9	878.1111	778.75886	259.58629
Total	27	482.4815	569.42315	109.58554

ANOVA
No. of adults

	Sum of squares	df	Mean square	F	Sig.
Between groups	2503197	2	1251598.370	5.068	.015
Within groups	5927114	24	246963.083		
Total	8430311	26			

Post Hoc Tests-
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	-294.44444	234.26627	.221
	9.00	-740.66667*	234.26627	.004
6.00	3.00	294.44444	234.26627	.221
	9.00	-446.22222	234.26627	.069
9.00	3.00	740.66667*	234.26627	.004
	6.00	446.22222	234.26627	.069

*The mean difference is significant at the .05 level

Oneway-
Descriptives- Grain damage (out of 1000)

	N	Mean	Std.Deviation	Std.Error
3.00	9	41.0000	26.18683	8.72894
6.00	9	108.7778	117.90757	39.30252
9.00	9	242.6667	308.03977	102.67992
Total	27	130.8148	202.42568	38.95684

ANOVA
Grain damage (out of 1000)

	Sum of squares	df	Mean square	F	Sig.
Between groups	189568.5	2	94784.259	2.597	0.095
Within groups	875811.6	24	36492.148		
Total	1065380	26			

Post Hoc Tests- Multiple Comparisons-
Dependent Variable: Grain damage (out of 1000) LSD

(I)Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.
3.00	6.00	-67.77778	90.05202	.459
	9.00	-201.66667*	90.05202	.035
6.00	3.00	-67.77778	90.05202	.459
	9.00	-133.88889	90.05202	.150
9.00	3.00	201.66667*	90.05202	.035
	6.00	133.88889	90.05202	.150

*The mean difference is significant at the .05 level

Oneway-
Descriptives
No. of grubs

	N	Mean	Std. Deviation	Std. Error
Cotton Cloth Bag	3	1237.3333	723.02305	417.43755
Jute Bag	3	1765.6667	1319.24612	761.66710
Synthetic Cloth Bag	3	1041.0000	739.16439	426.75676
Black Cloth Bag	3	1176.6667	651.6141	376.20795
HDPE Bag	3	1043.0000	724.52812	418.30651
Mud Pot	3	5036.6667	5593.72294	3229.537
Plastic 100 g Bag	3	.0000	.00000	.00000
Plastic 100 g Bag	3	.0000	.00000	.00000
Plastic 100 g Bag	3	.0000	.00000	.00000
Total	27	1255.5926	2220.96445	427.42481

Oneway -Descriptives
No. of adults

	N	Mean	Std. Deviation	Std. Error
Cotton Cloth Bag	3	615.667	436.56882	252.05312
Jute Bag	3	763.3333	595.00112	343.52406
Synthetic Cloth Bag	3	550.6667	426.53527	246.26025
Black Cloth Bag	3	646.0000	445.83854	257.40500
HDPE Bag	3	558.3333	434.83854	250.60748
Mud Pot	3	1208.3333	1030.99240	595.24374
Plastic 100 g Bag	3	.0000	.00000	.00000
Plastic 100 g Bag	3	.0000	.00000	.00000
Plastic 100 g Bag	3	.0000	.00000	.00000
Total	27	482.4815	569.42315	109.58554

Oneway-
Descriptives
Kernel Damage (Out of 1000)

	N	Mean	Std. Deviation	Std. Error
Cotton Cloth Bag	3	133.0000	80.07496	46.23130
Jute Bag	3	193.0000	151.91774	87.70975
Synthetic Cloth Bag	3	107.0000	75.18643	43.40891
Black Cloth Bag	3	141.6667	88.00758	50.81120
HDPE Bag	3	110.6667	79.66388	45.99396
Mud Pot	3	482.6667	465.60964	268.81985
Plastic 100g Bag	3	5.0000	8.66025	5.00000
Plastic 100g Bag	3	3.6667	6.35085	3.66667
Plastic 100g Bag	3	.6667	1.15470	.66667
Total	27	130.8148	202.42568	38.95684

ANOVA
No. of grubs

	Sum of Squares	df	Mean square	F	Sig.
Between groups	58152130	8	7269016.231	1.867	.129
Within groups	70097631	18	3894312.815		
Total	1E+008	26			

ANOVA
No. of adults

	Sum of Squares	df	Mean square	F	Sig.
Between groups	4076949	8	509618.676	2.107	.090
Within groups	4353361	18	241853.407		
Total	8430311	26			

ANOVA
Kernel Damage (Out of 1000)

	Sum of Squares	df	Mean square	F	Sig.
Between groups	533090.7	8	66636.343	2.253	.073
Within groups	532289.3	18	29571.630		
Total	1065380	26			

Build-Up of Larval Population:

At the end of three months, 400 gauge plastic bags were found most effective in affording protection to stored wheat from the Khapra beetle. No larval stages were found in them. Similarly 200 gauge and 100 gauge plastic bags were also effective as no larval stages were recorded in them at the end of this period. However, 12 dead larvae were found in 400 gauge plastic bag. In 200 and 100 gauge plastic bags, dead larval count was 25 and 30 respectively. The maximum number of grubs (larvae) [749] was recorded in Mud pot and thus it proved to be most unsuitable container for affording protection from Khapra beetle. Thus, the bag structure in order of its effectiveness in arresting the larval population of *Trogoderma granarium* Everts was 400 gauge plastic bag > 200 gauge plastic bag > 100 gauge plastic bag > Synthetic cloth bag > HDPE bag > White cotton -cloth bag > Black cotton-cloth bag > Jute bag > Mud pot.

At the end of 6 and 9 months, the observations in 100, 200 and 400 gauge plastic bags were deferred as they showed no survival of grubs in the first 3 months of storage itself. The Mud pot remained least effective and recorded maximum number of grubs i.e. 2996.67 and 9363.67 at the end of 6 and 9 months respectively. It was interesting to note that the black cotton-cloth bag recorded more number of grubs than the white cotton-cloth bag. The general order of effectiveness of the remaining storage structures in containing the population build-up of grubs was; HDPE bag > Synthetic cloth bag > Black cotton-cloth bag > White cotton-cloth bag > Jute bag > Mud pot (Figure 3).

Build-Up of Adult Population:

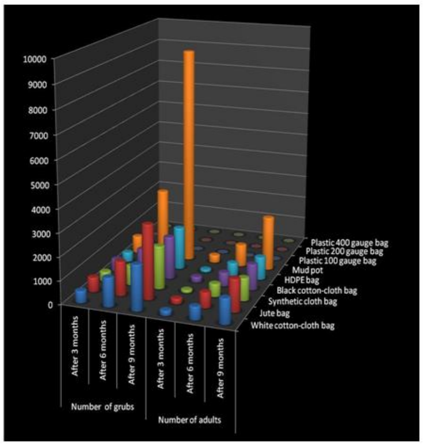

Figure 3: The Build-Up of Adult and Larval Population Over 9 Months

No adult stages were noticed in plastic bags of 400, 200 and 100 gauge at the end of three months and they thus proved to be the most effective storage structures among the ones used. In remaining storage structures; Synthetic cloth bag was found more effective while the Mud pot remained least effective. The highest numbers of adults were observed in Mud pot. The order of effectiveness of other containers used, in ascending order was; HDPE bag > Synthetic cloth bag > Black cotton-cloth bag > White cotton-cloth bag > Jute bag (Figure 3).

Grain Damage:

Synthetic cloth bag varied little among themselves and remained superior over white cotton-cloth / black cotton-cloth bags while the least effective container was Mud pot. The observations in 100, 200 and 400 gauge plastic bags were deferred after the end of three months as they showed no survival of grubs in the first 3 months of storage itself. Maximum percentage of grain damage was recorded in Mud pot (Figure 2) while it was least in HDPE bags. The percentage of grain damage in general descending order was; Mud pot < Jute bag < Black cotton-cloth bag < White cotton-cloth bag < HDPE bag < Synthetic cloth bag (Figure 4).

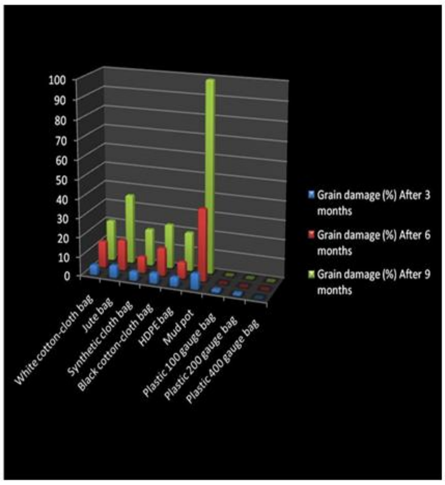

Figure 4: Grain Damage (%) due to Khapra Beetle in Various Storage Structures

DISCUSSIONS

It was noticed that 400, 200, 100 gauge plastic bags were most effective in comparison with other bags probably due to unfavourable micro-environment. The success of these sealed plastic bags of various gauges is attributed to the exhaustion of the limited oxygen supply due to consumption by insects and grains. After certain period of time the insects died for want of oxygen. It was noticed that with increase in the thickness of the bag the survival percentage decreased. This was arrived at by the dead-count of adults and grubs. Grain damage was inversely proportional to the thickness of the bags.

Synthetic cloth bags and HDPE bags offered more protection than other remaining bags. The synthetic nature of the fiber probably has made the movement of the beetle difficult thereby affecting its growth and development.

Commonly used jute bags were found to harbour comparatively more population and thereby resulted in more grain damage. This is attributed to the availability of aeration in jute bags due to their structure.

White cotton-cloth bags were marginally superior over black ones. This may be due to negatively phototropic nature of the grubs and adults. Sohi (1947) reported that more food was consumed by *Trogoderma granarium* Everts in constant darkness. Ismail et al. (1989) and Pasek (1998) reported that the larval survival of *Trogoderma granarium* Everts was 81% in constant darkness as against 51% in constant light. Rahman and Sohi (1939) reported that larvae and adults of *Trogoderma granarium* Everts are negatively phototropic through most of their lives. However, it appears that this phenomenon is true only in the event of choice as it was noticed that the damage in white cotton-cloth bags was only marginally more and was statistically insignificant.

Mud pot noted the maximum damage and maximum population build-up probably due to favourable conditions for the development of Khapra beetle. It literally mimicked traditional conditions of storage and was found to harbor enormous numbers of test insects thereby making the destruction total. It has provided the hot and dry microclimate which is congenial to the temperament of the Khapra beetle in addition to the darkness inside the pot.

Thus, the order of the effectiveness of different containers used was 400 gauge plastic bag > 200 gauge plastic bag

> 100 gauge plastic bag > HDPE bag > Synthetic cloth bag > white cotton-cloth bag > black cotton-cloth bag > Mud pot. Highland (1991) reported that packaging provides a physical barrier that prevents the infestation by insects.

It is concluded that plastic bags with proper sealing are better for storage of wheat. Alternatively, bags made of synthetic material can be used. In the event of their non-availability white cotton-cloth bags are recommended over jute or other bags.

The packaging, therefore, is an important parameter to be considered for avoiding / arresting the Khapra beetle infestation more importantly so because it has both invader and (medium) penetrative capabilities. This basic consideration shall be helpful in deciding the further components like bag impregnation/ use of vegetable oils/inert material in the integrated management of Khapra beetle.

CONCLUSIONS

Trogoderma granarium Everts is a major threat of stored grains products and having a status of a dangerous quarantine pest. Various control methods was implemented to control them. One of an alternative control methods *i.e*. the use of modified storages structures. The outcome of the present research were 400, 200, 100 gauge plastic bags were most effective in comparison with other bags probably due to unfavourable micro-environment. After certain period of time the insects died because of the less supply of oxygen. Grain damage was inversely proportional to the thickness of the bags. Whereas Mud pot noted the maximum damage and maximum population build-up probably due to favourable conditions for the development of Khapra beetle. Hence, it is concluded that plastic bags with proper sealing are better storage structures as compared to other bags. Therefore, the packaging is an important parameter to be considered for avoiding / arresting the Khapra beetle infestation. This modified storage structures are considered as a part of IPM module/concord.

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REFERENCES

1. *Banks, H.J. (1977). Distribution and establishment of Trogoderma granarium Everts (Coleoptera: Dermestidae) climatic and other factors. J. Stored Prod Res., 13, 183 – 202.*
2. *El Nadi, A.H., Elhag, E.A., Zaitoon, A.A. &Al-Doghairi, M.A. (2001). Toxicity of three plants extracts to Trogoderma granarium Everts (Coleoptera: Dermestidae).Pak. J. Biol. Sci., 4, 1503 – 1505.*
3. *EPPO. (1990). Data sheets on Quarantine pests-Trogoderma granarium, @ http://www.eppo.org/QUARANTINE/insects/Trogoderma_granarium/TROGGA_ds.pdf., A2:121.*
4. *Hill, P. (1983). Agricultural insect pests of the tropics and their control. Cambridge Univ. Press. Pp; 746.*
5. *Highland, H. A. (1991). Protecting packages against insects. Ecology and Management of Food Industry Pests. pp 345-350.*
6. *HT Media. (2007). Russia suspends import of Indian plant products. PTI, Moscow, posted: Wed, Jan23, 2008: 4:26 PM IST @http://www.livemint.com/Articles/PrintArticle.aspx.*
7. *Irshad, M. &Iqbal, J. (1994). Phosphine resistance in important stored grain insect pests in Pakistan. Pak. J. Zool. 26(4),347-350*

8. *Ismail, I. UI., Mostafa, T.S. & El-Keridees, B.B.(1989). Effect of food and light reproductive capacity and rate of infestation of Trogoderma granarium Everts. Bull.Soc. Entomol. Egypte, 68,159-168.*

9. *Kerr, J.A. (1981).Khapra beetle returns. Pest control, 49(12), 24 – 25.*

10. *Noling, J.W. &Becker, J.O. (1994). The challenge of research and extension to define and implement alternatives to methyl bromide. J. Haematol., 26, 573 – 586.*

11. *Pasek, J.E. (1998). Khapra beetle (Trogoderma granarium Everts): pest initiated pest risk assessment. USDA APHIS, Raleigh, NC., Pp.32.*

12. *Price, L.A., Mills, K.A. (1988). The toxicity of phosphine to the immature stages of resistant and susceptible strains of some common stored product beetles and implications for their control. J. StoredProd. Res., 24, 51–59.*

13. *Rahman, K. A. & G.S. Sohi. (1939). Observations on the reaction of the dermestid beetle Trogoderma khapra.Arr to light.J. Ind. Entomol, 1, 57-63.*

14. *Reuters, India. (2006). Russia bans plant products from India due to pest. Reuters News dated Wed Jan 23, 2008, 2:46 pm IST @ http://in.reuters.com/articlePrint?articleId=INIdia-31546120080123*

15. *Singh, S.R. (1990). Insect pests of tropical food legumes. Wiley, Chichester 451 pp.*

16. *Sohi, G. S. (1947). Studies on the stored grain pests in Punjab. VIII. Effect of constant light and darkness on the development and reproduction of and on amount of food consumed by Trogoderma granariumEverts.Indian J. Ent., 9,143-147.*

17. *Su H.C.F. (1991). Toxicity and repellency of Chenopodium oil to four species of stored product insects, J. Entomol. Sci., 26,178-182.*

18. *Taylor, R.W.D. (1994). Methyl bromide. Is there any future for this fumigant. J. Stored Prod. Res., 30,253 – 260.*