Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 6[11] October 2017 : 14-19

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

REVIEW ARTICLE **OPEN ACCESS**

Khapra Beetle (*Trogoderma granarium* Everts): A Food Security Threat

Amit Singh[1], Phool Chand[1], R. Vishwakarma[2*] and Chandan Kumar Singh[3]
pcshastri_ent@yahoo.com, and entoramanuj@gmail.con and singhamitbckv1990@gmail.com
[1]Department of Entomology, Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, 741235, W. B.
[*2]Department of Entomology, Bihar Agricultural University, sabaur-813210, Bhagalpur, Bihar
[3]Department of Plant Pathology, N. D. U. A.&T., Kumarganj, Faizabad- 224229 (U.P.), India

ABSTRACT

Khapra beetle, Trogoderma granarium Everts (Coleoptera: Dermestidae) is a serious pest of stored grains and stored products (groundnut, cotton, barley, rice, millet, sesame, sorghum, wheat, maize and cowpea etc.) with quarantine status is one of the invasive species feared around the world. Identification of adult khapra beetle on the basis of morphology is difficult due to its similarity with other dermestids, thus study of genitalia will specify the species and also aim at understanding its reproduction and fecundity. Damage can be severe with weight losses of between 5-30 per cent and in extreme cases 70 per cent. Besides weight losses it also reduces the grade of grain, unfit for consumption and may result in less profit for wholesalers. Apart from the destruction of grain dry products by Khapra beetle, ingesting products contaminated with body parts, setae and cast larval skins can result in gastro-intestinal irritation. Asthmatics and sensitized individuals are also at risk, as contaminants are highly allergenic. Detection of Khapra beetle live or dead attracts serious trade restrictions and economic fallout. It attracts strict phytosanitary regulation by many countries in order to restrict the pest at the boundaries. The pest is difficult to control owing to its diapause. Therefore, necessary to design a system's approach to tackle this pest. The use of methyl-bromide or other fumigants to eradicate or control Khapra beetle will likely produce adverse effects on the environment and human health. Methyl bromide is an ozone-depleting substance, and human exposure to high concentrations can result in the failure of the central nervous and respiratory systems. Therefore alternative of MBR has to be searched for safer control of Khapra beetle in quarantine.

Keywords: *Trogoderma granarium Everts. Stored product, Quarantine, Detection, Quantitative losses, qualitative losses, control.*

Received 01.06.2017 Revised 15.07.2017 Accepted 18.08.2017

INTRODUCTION

The khapra beetle, *T. granarium* Evert (Coleoptera: Dermestidae) is also called *T. affrum, T. Arrow.* Khapra beetle, *T. granarium* was first time reported from India in 1894 by Cotes and took their ranked as one of the 100 worst invasive species worldwide [30]. It is principally a serious pest of stored grain products under hot dry conditions. Complete destruction of grain and pulses may take place in a short time. However in such areas, it lives at the inner edge of the expanding hot zone of stacks or bulk, in which heating has been induced by the activity of other species. Damage can be severe with weight losses of between 5-30% and in extreme cases 73% [4].

The status of *T. granarium* is of extreme economic importance due to its continued occurrence on produce imported from countries where it is indigenous, and the potential for spread due to increasing use of dry cargo containers and roll-on and roll-off road transport, make it a potential intimidation to the worldwide food security. Regrettably, the pest is very common in granaries, godowns, bins, silos as well as farmhouses in India.

Severe infestations of grain by khapra beetle may make it unfit for consuming or marketable. Grain quality may decrease due to depletion of specific nutrients. In wheat, maize, and sorghum grains, there was a significant decrease in crude fat, total carbohydrates, sugars, protein nitrogen, starch contents, true protein contents, vitamins thiamin, riboflavin, niacin, total lipids, phospholipids, galactolipids, polar and non-polar lipids; increases in the levels of uric acid, moisture, crude fiber, total protein and antinutrient polyphenol [24, 25] were observed. Khapra beetle, *T. granarium* have been assigned the pest a status as a technical barrier to trade due to quality deteriorating characteristics [36]. This is a native pest of India but prefers hot and dry climates of Asia, Africa and Eurasia [7] but also reported in USA [18].

HOST RANGE:
Groundnut, Cotton, Barley, Rice, Millet, Sesame, Sorghum, stored products (dried stored products), Wheat, Maize and Cowpea etc.

IDENTIFICATION
There are about 134 species of Trogoderma in the world [20] with 12 of them occurring in storage facilities. Taking into account that many Trogoderma species taking place in storage facilities closely resemble *T. granarium,* the correct identification of the pest is not an easy task. Thankfully, there are many old and recent identification keys available for larvae and adults of the *T. granarium* (Bousquet, 2010)

Most of the time, identification is based on an examination of the adult's genitalia or larval mouthparts, especially when the specimen is damaged with missing body part. Identification of eggs and pupae based on external features is currently not possible [29]. The numbers of species of Trogoderma are namely *T. granarium* (Everts), *T. variable* (Ballion), *T. glabrum* (Herbst), *T. grassmani* (Beal), *T. ornatum* (Say), *T. parabile* (Beal), *T.simplex* (Jayne), *T. sternalesternale* (Jayne), *T. sternalemaderae* (Beal), *T. sternaleplagifer* (Casey), *T. inclusum* (Le Cont) and *T. versicolor* (Creutzer).

BIOLOGY AND MORPHOLOGY

Eggs: Female begins to lay eggs on the grains, singly or sometimes in clusters of 2 - 5. The eggs are initially milky-white, later pale-yellowish; typically cylindrical, 0.7 mm long and 0.25 mm broad; one end rounded, the other more pointed and bearing a number of spine-like projections, broader at the base and tapering distally. The egg period varies from 3 -10 days [35].

Larva: Total length of the first-instar larva is 1.6-1.8 mm, a little more than half of which consists of a long tail, made up of a number of hairs borne on the last abdominal segment. Body width is 0.25-0.3 mm, and colour uniformly yellowish-white, except for the head and body hairs which are brown. The head bears a short antenna of three segments. A characteristic feature of the larva is the presence of two kinds of body hairs: simple hairs, in which the shaft bears many small, stiff, upwardly directed processes; and barbed hairs, in which the shaft is constricted at regular intervals, and in which the apex consists of a barbed head. This brown or yellowish-brown head is as long as the combined lengths of four of the preceding segments. Simple hairs are scattered over the dorsal surface of the head and body segments. The tail consists of two groups of long simple hairs, borne on the 9th abdominal segment. Barbed hairs are found in pairs of tufts, borne on certain abdominal tergites. As the larva increases in size, the colour changes progressively from the pale yellowish-white of the first-instar larva to a golden or reddish-brown. The density of the body hairs increases but these hairs and the tail become much shorter in proportion to the length and breadth of the larval body, and in the 4th instar the hairs give the appearance of four dark transverse bands. The mature larva is approximately 6 mm in length and 1.5 mm in breadth [35]. Morphologically, the mature larva of Khapra beetle can be separated from that of *T. versicolor*by the absence of a dark pretergal line on the 7th and 8th abdominal segments, such a line being faint or absent on the 7th segment and never present on the 8th segment in Khapra beetle [35] and three pairs of legs. Larval period is 20 - 40 days [6].

Pupa: At the last ecdysis, the larval skin splits, but the pupa remains within this skin for the whole of its life. The pupa is of the exarate type; male smaller than female, average lengths being 3.5 mm and 5 mm, respectively [35]. Whitish colour [6]. Pupal period is 4 - 6 days. Pupation takes place in the last larval skin among the grains.

Adult: Oblong-oval beetle; about 1.6-3.0 mm long by 0.9-1.7 mm wide; males brown to black, with indistinct reddish-brown markings on the wing covers; females are slightly larger than males, and lighter in colour; antennae are 11-segmented; the head is small and usually deflexed. Mated female live 4-7 days while unmated female live 20-30 days and male live 7-12 days. Complete development from egg to adult varies from 26-220 days.

DAMAGE SYMPTOMS
T. granarium may remain hidden deep in the stored food for relatively long periods. The greatest damage is done in summer from July to October. In bag stores, the first signs of infestation are masses of hairy cast larval skins, which gradually push out from the crevices between sacks; this is a sign that the stored food should be fumigated immediately. The grub crawls over and consumes the grain. The grubs eat the grain near the embryo or at any other weak point and from there proceed inwards. They usually confine themselves to the upper 50 cm layer of grains in a heap or to the periphery in a sack of grains. They can

reduce the grain to a mere frass. Since the larvae are positively thigmotactic, they can be collected by merely placing gunny bags on a heap of grain.

DETECTION AND INSPECTION METHOD:

The most likely stage to be seen during inspection is the larva and the most usual evidence is accumulated cast larval skins. Trapping is another way to detect or monitor the presence of *T. granarium*. Use of pheromone, food attractant or combination traps for the early detection of khapra beetle in commodities and in structures can be an important part of quarantine, detection or control programmes. Special attention should be given to any produce from the areas where the pest is indigenous, (the potential for spread due to international trades make it a continued threat to many countries) especially oilseeds and oilseed products, pulses, cereals and gums, as well as used and new sacks and hessian from these areas. In warehouses which are suspect, examine cracks and crevices and look behind any paneling against walls. In ships, look also under rust scale, under timber coverings of tanks, on ledges, etc. In dry cargo containers, look between floor boards and behind linings.

RESTRICTIONS ON NONCOMMERCIAL AND COMMERCIAL COMODITIES IMPORTED FROM COUNTRIES WHERE KHAPRA BEETLE IS KNOWN TO OCCUR

The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) has established restrictions on the importation of commercial and noncommercial shipments of rice, soybeans, *Cicer* species (e.g., chickpeas), and safflower seeds from countries where Khapra beetle (*T. granarium*) is known to occur. These restrictions apply to all countries where Khapra beetle is known to occur, including Afghanistan, Algeria, Bangladesh, Burkina Faso, Cyprus, Egypt, India, Iran, Iraq, Israel, Libya, Mali, Mauritania, Morocco, Myanmar, Niger, Nigeria, Pakistan, Saudi Arabia, Senegal, Sri Lanka, Sudan, Syria, Tunisia, Turkey, and the United Arab Emirates.

The introduction and establishment of this beetle into the United States poses a serious threat to stored agricultural products, including spices, grains, and packaged foods. Previous detections of Khapra beetle have resulted in massive, long-term control and eradication efforts at great cost to the American taxpayer. Noncommercial quantities are defined as amounts for personal use and not for resale, including those transported in international passenger baggage, by mail, or by courier. The Khapra beetle's size and other characteristics make it very difficult for members of the general public to identify. Returning travelers must declare all agricultural items on their Customs Declaration Form or verbally to a U.S. Customs and Border Protection officer or agriculture specialist at the first U.S. port of entry. Failure to declare agricultural items can result in up to $10,000 in fines and penalties. Commercial shipments must be inspected and accompanied by a phytosanitary certificate with an additional declaration stating that the shipment has been inspected and found free of Khapra beetle. A phytosanitary certificate or phytosanitary certificate of re-export with the same additional declaration is also required for commercial shipments originating from countries known to have Khapra beetle that make entry into another country before re-exportation to the United States. The means of conveyance must also be inspected and found free of Khapra beetle [4].

ESTIMATE OF ECONOMIC IMPACT ON PRODUCTION, ALLIED INDUSTRIES AND NATIVE ECOSYSTEMS

Trade impact:

International grain markets are becoming more discerning but Australian industry to continue to be victorious, it is essential that we acclimatize to these changing markets especially given that 75% of our annual harvest is exported. Customers continue to demand grain that is totaly free from insect and diseases. Particularly in the case of Khapra beetle it would be of the unwelcome for Australia to be able to claim freedom of this pest. When Australia was erroneously listed as "Khapra beetle" country in the late 1940"s, it took over 15 years of lobbying and publication to have this stigma removed [17]. Many Australian export markets could disappear immediately if Khapra beetle is found to be present [11]. Under 4 scenarios in an assessment of the potential economic impact of Khapra beetle in Western Australia, costs associated with export market losses ranged from $46 million/year to 117 million/year, while the present value of costs over a 30 year period ranged from $200 million to $1.6 billion. Khapra beetle could be controlled to acceptable levels by existing (phosphine) or additional (methyl bromide, heat, controlled atmospheres, irradiation) control measures. In this case the costs of Khapra beetle to Western Australia would be substantially less than the estimates quoted above.

Environmental Impact:

Apart from the destruction of grain products by Khapra beetle, ingesting products contaminated with body parts, setae and cast larval skins can result in gastro-intestinal irritation. Asthmatics and sensitised individuals are also at risk, as contaminants are highly allergenic. Since infestations would most likely be confined to grain storage facilities and other buildings, this pest is not expected to have significant impacts on natural environments or endangered / threatened species [36]. The use of methyl-bromide or other fumigants to eradicate or control Khapra beetle will likely produce adverse effects to the environment and human health. Methyl bromide is an ozone-depleting substance, and human exposure to high concentrations can result in the failure of the central nervous and respiratory systems [37].

CONTROL MEASURES:

Physical:

The occurrence of resistance development by the khapra beetle to phosphine has forced the scientists to look for alternatives such as modified atmospheres, use of elevated temperatures and others, which had conventionally been used for many years in the past. Diapausing larvae of the *T. granarium* have been reported as the most tolerant stored product pest to a high - CO_2 atmosphere, requiring very long exposure times for efficient control [32]. Complete mortality was observed at >60% CO_2 after 17–30 days exposure at 25–30^{o}C [32, 46].

Developmental stages of *T. granarium* were exposed to low-pressure (50 mmHg) within test chambers containing cocoa beans (R.H. 55%, 30o_C). Under those conditions, the most tolerant stage (egg) recorded complete mortality after 46 h. Under certain circumstances this vacuum treatment could provide a good quarantine solution. Recent experiments have shown that [27, 29] are necessary for complete mortality even under 'unrealistic' freezing temperatures (-16^{0}C) [15]. On the other hand, heat treatment has been well documented as an effective alternative against *T. granarium* [44, 8, 31]. Such methods may be practically applied mainly in countries where summer temperature exceeds 40^{o}C and a little energy cost will incur to maintain temperature at 60^{o}C. Exposure of *T. granarium* to 60^{o}C for 30 min is sufficient to achieve 100% kill of all stages [10]. Moreover, when pupae were exposed to 45^{o}C for 48 h the emerging adults were sterile. Despite the great potential of this method as a control treatment against the khapra beetle, no recent literature data are available. Gamma or other types of irradiation have also been evaluated as a quarantine treatment against the khapra beetle [38, 39, 16]. Both gamma equipment containing radioisotopes such as cobalt 60 and electron beam accelerators can be used to disinfest stored commodities. Recent experimental data suggested that the effective quarantine irradiation dose for khapra beetle was 200 Gy. Apart from gamma, the UVC irradiation has also been evaluated as a control agent against the khapra beetle. Eggs and pupae were the most sensitive and tolerant stages, respectively [19] currently, several stored grains and pulses are commercially irradiated in Indonesia, France and South Africa [47].

Biological:

The biological agent (predators, parasitoids, nematodes, pathogens etc.) have also been studied as control agents against the *T. granarium*. The entomopathogens *Mattesia trogodermae* Canning (Protozoa: Neogregarinida) [21], *Metarhizium anisopliae* (Metschinkoff) (Ascomycota: Hypocreales) [28], 2011) and *Bacillus thuringiensis* Berliner (Bacilli: Bacillaceae) [1], the parasitic nematodes *Steinernema feltiae* (Filipjev) [26] and *Steinernema masoodi* (Ali, Shaheen, Pervez and Hussain) (Rhabditida: Steinernematidae) [2] the ectoparasitoid *Laelius pedatus* (Say) and the generalist predator *Xylocoris flavipes* (Reuter) (Hemiptera: Anthocoridae) [41] have been found to parasitize or prey on the khapra beetle.

Atmospheres

Annis [3] reported that 16 days exposure at 80% CO_2 (20-30°C) or 0.1% oxygen at 20-29°C for more than 20 days was required to eliminate Khapra beetle [46], High pressure CO2 may be effective with only brief exposures (a few hours).

HEAT

Heat treatment appears to be a potentially useful technique for quarantine treatment of heat tolerant commodities against Khapra beetle. There is a surprising quantity of data available to substantiate this. [22] heat dosages aimed at to eliminate Khapra beetle. It is suggested that a conservative heat dosage of at least 120 minutes at 55°C at the site of the infestation would be adequate to eliminate Khapra beetle [43].

IRRADIATION

Rees and Banks [43] refer to many laboratory-based studies on use of irradiation to sterilize Khapra beetle for its control. Most of these studies are directed at adult insects, often not the stage of concern in quarantine treatments. Studies on effectiveness of irradiation on apparently diapause larvae are not adequate to base a sound assessment on, but they suggest diapause larvae are very tolerant to irradiation at low temperatures (< 20ºC). Data is available and done by Rahalkarand Nair [40].

PLANT EXTRACT

Repellence and toxicity of a plethora of plant species against *T. granarium* have been evaluated [12, 13, 33, 42, 23]. The use of neem (*Azadirachta indica*) essential oil as a fumigant or as seed powder mixed into grain seemed to be an effective and cheap method to control the pest especially in developing countries [45, 34, 14].

Chemical

Consignment to be fumigated with Methyl Bromide @ 80 gm/cu.m. for 48 hrs and endorsement of additional declaration in Phytosanitary Certificate "The goods are free from *T. granarium*).

Apply aluminum phosphide (available in 0.6 g and 3 gram tablets) @ 3 tablets (3 gram each) per ton of food grains lot with help of an applicator. Choose the fumigant and work out the requirement based on the following guidelines.

REFERENCES

1. Ahmedani, M. S., Khaliq, A., Haque, M. I., (2007). Scope of commercial formulations of *Bacillus thuringiensis* Berliner as an alternative to methyl bromide against *Trogoderma granarium* Pakistan journal of Botany, 11, 316–320.
2. Ali, S. S., Asif, M., Sirvastava, S. P., Shankar, P., (2011). First report on susceptibility of khapra beetle (*Trogoderma granarium*) against *Steinernema masoodi* and its in vivoproduction, Trends in Bioscience, **4**: 140–141.
3. Annis, P.C., (1987). Towards rational controlled atmosphere dosage schedules: a review of current knowledge. Proc. 4th Working Conf Stored-Prod. Prot., Tel Aviv, Isreal, 128-148.
4. Anonnymous, (2005). Plant health Australia grains industry bio-security plan, 1-21.
5. Anonnymous, (2012). Plant Protection and Quarantine, *APHIS fact sheet,* 1-2.
6. APHIS, (1984). United States Action plan; Khapra beetle *Trogoderma granarium* Everts, APHIS USDA, USA Ctsheet,1-114.
7. Banks, H. J., (1977). Distribution and establishment of *Trogoderma granarium* Everts (Coleoptera :Dermestidae): Climatic and other influences. Journal of Stored Product Research, 13, 183-202.
8. Battu, G. S., Bains, S. S., Atwal, A. S., (1975). The lethal affects of high temperature on the survival of the larvae of *T. granarium* Everts. Indian Journal of Ecology, 2, 98–102.
9. Bousquet, Y., (2010). Beetles Associated with Stored Products in Canada: An Identification Guide. Agri. Canada Research Branch Publication, 19-54.
10. Burges, H. D., (2008). Development of the khapra beetle, *T. granarium*, in the low part of its temperature range Journal of Stored Product Research, 44, 32–35.
11. Butcher, M. J., Dean, K. R., (1995). Management plan for Warehouse beetle in Western Australia. Agriculture Protection board of Western Australia,1-16.
12. Cis, J., Nowak, G., Kisiel, W., (2006). Antifeedant properties and chemotaxonomic implications of sesquiterpene lactones and syringin from *Rhaponticum pulchrum*. Biochemical Systematics and Ecology, 34, 862–867.
13. Derbalah, A. S., 2012. Efficacy of some botanical extracts against *Trogoderma granarium* in wheat grains with toxicity evaluation. Science World Journal Article ID, 639854.
14. Egwurube, E., Magaji, B. T., Lawal, Z., (2010). Laboratory evaluation of neem (*Azadirachta indica*) seed and leaf powders for the control of khapra beetle, *Trogoderma granarium* (Coleoptera: Dermestidae) infesting groundnut. International Journal of Agriculture and Biolog,12, 638–640.
15. Eliopoulos, P. A., Prasodimou, G. Z., Pouliou, A.V., 2011.Time-mortality relationships of larvae and adults of grain beetles exposed to extreme cold. Crop Protection 30, 1097–1102.
16. El-Lakwah, F. M. A., Gharib, M. S. A., (2005). Efficacy of diatomaceous earth dust under modified atmospheres against some stored grain insects. Annals of Agriculture Sciences, 43, 449–460.
17. Emery, R. N., (1999).Warehouse Beetle (*Trogoderma variable*). Farmnote No. 77, Agriculture Western Australia. Enclosures for pest and quality management of bagged milled rice. Entomological Research, 46, 311–355.
18. FAO, (1981).United States–khapra beetle infestations reported. FAO Plant Protec. Bull. 29-30.
19. Ghanem, I., Shamma M., (2007). Effect of non-ionizing radiation (UVC) on the development of *Trogoderma granarium* Everts. Journal of Stored Product Research, 43, 362–366.
20. Hava, J., (2011). Dermestidae of the world (Coleoptera) Catalogue of the all known taxons.
21. Henry, J. E., (1981). Natural and applied control of insects by protozoa. Annual Review of Entomology, 26, 49–83
22. Husain, M. A. (1923). Preliminary observation on lethal temperatures for the larvae of Khapra beetle, pest of stored wheat. Proc. Fourth Entomological Meeting, Pusa, 240-248.
23. Jakhar, B. L., Jat, S. L., (2010). Efficacy of plant oils as grain protestants' against khapra beetle *Trogoderma granarium* Everts in wheat. Indian Journal of Entomology, 72, 205–208.
24. Jood, S., Kapoor, A. C., Singh, R., (1995). Polyphenol and phytic acid contents of cereal grains as affected by insect infestation. Journal of Agriculture and Food Chemestry, 43, 435-438.
25. Jood, S., Kapoor, A. C., Singh, R., (1996a). Chemical composition of cereal grains as affected by storage and insect infestation. Tropical Agriculture, 73, 161-164.
26. Kamionek, M., Sander, H., (1977). The pathogenicity of *Neoaplectana carpocapsae* in relation to its hosts in two-species combinations. Journal of Agricultural Technology, 1, 43–54.
27. Karnowski, W., (2002). *Trogoderma granarium*, diagnostic protocols for regulated pests. Bull. OEPP/EPPO, 32, 299–301.
28. Khashaveh, A., Safaralizadeh, M. H., Ghosta, Y., (2011). Pathogenicity of Iranian isolates of *Metarhizium anisopliae* (Metschinkoff) (Ascomycota: Hypocreales) against *Trogoderma granarium* Everts (Coleoptera: Dermestidae). Bihar Biology, 51–55.

29. Kucerova, Z., Hromadkova, J., Stejskal, V., (2010). External egg morphology of common stored-product pests from the families Anobiidae (Ptininae) and Dermestidae (Coleoptera). In: Carvalho, M. O., Fields, P. G., Adler, C. S., Arthur, F. H., Athanassiou, C. G., Campbell, J. F., Fleurat-Lessard, F., Flinn, P. W., Hodges, R. J., Isikber, A. A., Navarro, S., Noyes, R. T., Riudavets, J., Sinha, K. K., Thorpe, G. R.., Timlick, B. H., Trematerra, P., White, N. D. G., editors. Proc. of the 10th Intern Working Conference on Stored Prod. Protec. Portugal. Berlin, Germany, 135–138.
30. Lowe, S., Browne, M., Boudjelas, S., DePoorter, M., (2000). 100 of the World's Worst Invasive Alien Species: a selection from the global invasive species database. Invasive Species Specialist Group, 1-11
31. Mookherjee, P. B., Jotwani, M. G., Yadav, T. D., Sircar, P., (1968). Disinfestation of stored seeds by heat treatment. Indian Journal of Entomology, 30, 197–202.
32. Navarro, S., Finkelman, S., Donahaye, E., Dias, R., Rindner, M., Azrieli, A., (2002). Integrated storage pest control methods using vacuum or CO_2 in transportable systems Proc. of the IOBC/WPRS, 25, 207–214.
33. Nenaah, G. E., 2011. Toxic and antifeedant activities of potato glycoalkaloids against *T. granarium* (Coleoptera: Dermestidae). Jornal of Stored Product Research, **47**: 185–190.
34. Odeyemi, O. O., Ashamo, M. O., 2005. Efficacy of neem plant (*Azadirachta indica*) extracts in the control of *Trogoderma granarium*, a pest of stored groundnuts. Journal of Plant Disease Protection, 112:586–593.
35. OEPP/EPPO, (1981). Data sheets on quarantine organisms, *Trogoderma granarium* Bulletin,12, 11.
36. Pasek, J. E., (1998). USDA Pest Risk Assessment; Khapra beetle *Trogoderma granarium*. USDA APHIS Center for Plant Health Science and Technology New Castle USA,1-17
37. Pasek, J. E., 2004. USDA Pest Risk Assessment: Khapra Beetle. USDA APHIS, Center for Plant Health Science and Technology Raleigh Plant Protection Center 1017 Main Campus Dr. Suite 2500 Raleigh, NC 27606-5202 The center for Environmental and Regulatory Information Systems, Purdue uni.USA, 1-17
38. Quarles, W., (1992). Diatomaceous earth for pest control. IPM Practitioner, 14, 1–11.
39. Quarles, W., Winn, P. S., (1996). Diatomaceous earth and stored product pests. IPM Practitioner, 18**,** 1– 107.
40. Rahalkar, G. W., Nair, K. K., (1968). Influence of diapause on the radio sensitivity of *Trogoderma granarium*. In Isotopes and Radiation in Entomology", Part 3, Proc. Ser. Int. Atomic Energy Agency, STI/PUB/166, 149-154.
41. Rahman, M. M., Islam, W., Ahmad K. N., (2009). Functional response of the predator *Xylocoris flavipes* to three stored product insect pests. International Journal of Agricultur and Biotechnology, 3, 317
42. Rao, N. S., Sharma, K., Sharma, R. K., (2005). Antifeedant and growth inhibitory effects of seed extracts of custard apple *Annona squamosa* against khapra Beetle *Trogoderma granarium.* Journal of Agricultural Technology, 43-49
43. Rees, D. P., Banks, H. J., (1999). The Khapra beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae), a quarantine pest of stored products: Review of biology, distribution, monitoring and control. Stored Grain Research Laboratory, CSIRO Entomology, Canberra, Australia, 1-17
44. Saxena, B. P., Sharma, P. R., Thappa, R. K., Tikku, K., (1992). Temperature induced sterilization for control of three stored grain beetles. Journal of Stored Product Research, 28, 67–99.
45. Singh, R. P., P. K., (1986). Kataria Deoiled neem kernel powder as protectant of wheat seeds against *Trogoderma granarium* Everts. Indian Journal of Entomology, 48, 119-120.
46. Spratt, E., Dignan, G., Banks, H. J., (1985). The effects of high concentrations of carbon dioxide in air on *Trogoderma granarium* Everts (Coleoptera: Dermestidae). Journal of Stored Product Research, 21, 41–46.
47. Stibick, J., (2007). New Pest Response Guidelines: khapra Beetle. USDA–APHIS–PPQ–Emergency and Domestic Programs, Riverdale, Maryland, 1-114
48. Yadav, S., Mahlaj, J. C., (2002). Bio-efficacy of carbon dioxide concentration and its exposure against khapra beetle in wheat grain. Indian Journal of Entomology, 64, 130–137.

CITATION OF THIS ARTICLE

A Singh, P Chand, R. Vishwakarma and C K Singh. Khapra Beetle (*Trogoderma Granarium* Everts): A Food Security Threat. Bull. Env. Pharmacol. Life Sci., Vol 6[11] October 2017: 14-19