KHAPRA BEETLE (*TROGODERMA GRANARIUM* EVERTS): A SERIOUS THREAT TO FOOD SECURITY AND SAFETY

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Concern has been expressed that stored grain pests especially the Khapra beetle has posed serious threat to global food security and safety. Its great economic importance is due to its capability to cause huge loss in stored grains through voracious feeding and heating of grains, in larval ability to withstand starvation for up to 3 years as well as in its ability to live on food with very low moisture content. *T. granarium* is of quarantine concern because its spread is mainly through international trade. Inspection at ports and entry points provide an effective way to restrict entry of this pest. The development of resistance in this pest against conventional insecticides such as phosphine, malathion, actellic and some pyrethroids has further aggravated its economic importance. Inspite of the economic importance of this pest, no comprehensive review was available in the literature which may guide the food policy makers, food security and plant protection workers about the quantitative as well as qualitative losses caused by this pest. This paper presents a comprehensive review of the economic losses cause by this pest of quarantine importance; its biology, habitat as well as IPM.

Keywords: Quantitative losses, qualitative losses, biology, geographical distribution, *Trogoderma granarium* Everts.

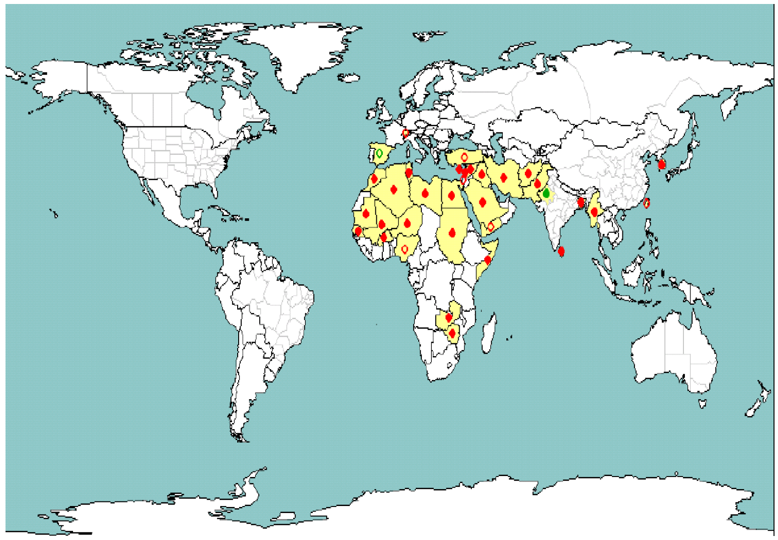
INTRODUCTION

The khapra beetle, *Trogoderma granarium* Everts also known as Trogoderme (dermeste) du grain (French), Khaprakafer (German), Escarabajo khapra (Spanish) is one of the world's most destructive stored-product pests. In fact, it has been recognized as an A_2 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. Regrettably, the pest is very common in granaries, godowns, bins, silos as well as farm houses in Pakistan. Control of this pest is not only vital to ensure food security and food safety situation but is pre-requisite for export of the surplus wheat and other cereal grains. Although, routine treatments of stored grains for domestic species of stored grain pests may control khapra beetle and sufficiently avert significant economic losses yet, development of resistance against the conventional pesticides has posed a new challenge for the researchers.

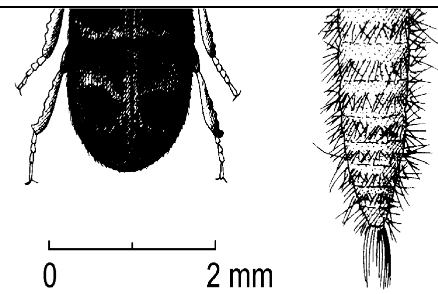
The WTO committee on SPS has also prohibited importation of cereals, oil seed commodities and similar grains, seeds, flours and meals, thereof, in order to protect domestic production and prevent the introduction and spread of this pest. This restriction is applicable to products originating in or consigned from Europe, Africa, Oceania and particularly the following Asian countries: Afghanistan, Bangladesh, Chinese Taipei, Cyprus, India, Iran, Iraq, Israel, Korea, Lebanon, Myanmar, Pakistan, Saudi Arabia, Sri Lanka, Syria, Turkey and Yemen and all other countries in which the Khapra beetle *T. granarium* has been reported (Fig-1). Such restrictions are supported by the facts that feeding by Khapra beetle larvae reduces the weight and quality of grain. In Pakistan estimates of storage losses of food grains due to insects have been reported to vary greatly; 4-10% (Huque *et al*., 1969), about 5.08% (Chaudhry, 1980), 5% (Ahmad, 1984), 3.5 – 25.5% (Irshad and Balouch, 1985).

In India, average damage levels ranged from 6% to 33% of grain in a single storage season, with maximum damage at 73% (Rahman *et al*., 1945). At optimal conditions of 36^{o}C and 15% infestation level, wheat lost 2.6% of its weight and 24% of its viability (Prasad *et al*., 1977). The loss of grain or costs of necessary treatment may result in less profit for wholesalers. Severe infestations of grain by khapra beetle may make it unpalatable or unmarketable. Grain quality may decrease due to depletion of specific nutrients. In wheat, maize, and sorghum grains, there was a significant decreases 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 (Jood and Kapoor, 1993; Jood *et al*., 1993; Jood and Kapoor, 1994; Jood *et al*., 1995; Jood *et al*., 1996a) were observed. Theses quality deteriorating characteristics of *Trogoderma* have assigned the pest a status as technical barrier to trade.

FIG-1 Geographical distribution of Khapra beetle



Chronological overview of Trogoderma



As a stored grain pest Khapra beetle *T. granarium* was first time reported from India in 1894 by Cotes. The latest literature reveals that the pest is present in more than 35 countries of the world (PASEK, 2004). This is native pest of India but prefers hot and dry climates of Asia, Africa and Eurasia (Burges, 1959; Banks, 1977) but also reported in USA (Jensen, 1954; Lindgren *et al*., 1955; Anonymous, 1978; FAO, 1981). It has attained a status of very common primary pest of stored wheat, rice and maize in the Indo-Pak subcontinent.

Biosystematics of khapra beetle

The *Trogoderma granarium* Everts belongs to family Dermestidae and order Coleoptera. The adults are harmless and oblong-oval in shape; about 1.6-3.0 mm long and 0.9-1.7 mm wide. The males are brown to black in color with indistinct reddish-brown markings on the wing covers. Whereas females are slightly larger than males, and lighter in color; antennae are 11-segmented; head is small and usually deflexed. The adults are short-lived, mated females living 4-7 days, unmated females 20-30 days and males 7-12 days; they do not fly and feed very little. Mating occurs about five days after emergence, and egg laying begins almost immediately. Single female is able to lay 50-90 cylindrical eggs with a number of spine-like projections. The eggs are initially milky-white, later become pale-yellowish. Depending upon the temperature, incubation period is 3-to 14 days. The larval stage of this pest is the destructive stage that causes heavy economic losses to stored grains and other food commodities. There are 5 to 6 instars of these larvae. 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 head is as long as the combined lengths of four of the preceding segments. 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 final instar larva is approximately 6 mm in length and 1.5 mm in breadth. A conspicuous feature of a khapra beetle infestation is masses of these hairy larvae and their cast skins. Complete development from egg to adult can occur from 26 to 220 days, depending upon temperature. Optimum temperature for development is 35°C. If the temperature falls below 25°C for a considerable period of time or if larvae are very crowded, they may enter diapause. They can survive temperatures below -8°C. In diapause, the larvae can molt but are inactive and may remain in this condition for many years (Anonymous, 1981). At the last ecdysis, the larval skin splits, but the pupa remains within this skin for the whole of its life. Larvae of *T. granarium* have been reported to survive for 6 months without food.The pupa is of the exarate type; male smaller than female, average lengths being 3.5 mm and 5 mm, respectively. The rate of increase of populations at 33-37°C is about 12.5 times per month.

Economical importance of *Trogoderma granarium*

Species of Trogoderma reported on cereals

There are about 115 species of *Trogoderma* in the world (Beal, 1982). Twelve species of *Trogoderma* genus (Table 1) have been reported as stored grain pests from different parts of the world but *T. granarium* is considered to be the most destructive species. Due to the reason, it has been included as in the list of A_2 quarantine pests.

Khapra beetele as food security threat

Table 1. Trogoderma species as stored grain pests

Order	Family	Species
Coleoptera	Dermestidae	*Trogoderma granarium* (Everts, 1898)
		Trogoderma variable (Ballion, 1878)
		Trogoderma glabrum (Herbst,1783)
		Trogoderma grassmani (Beal, 1954)
		Trogoderma ornatum (Say, 1825),
		Trogoderma parabile (Beal, 1954)
		Trogoderma simplex (Jayne, 1882)
		Trogoderma sternale sternale (Jayne, 1882)
		Trogoderma sternale maderae (Beal, 1954)
		Trogoderma sternale plagifer (Casey, 1916
		Trogoderma inclusum (Le Cont, 1854).
		Trogoderma versicolor (Creutzer, 1799)

The storage losses are mainly caused by insect pests like *Rhizopertha, dominica, Trogoderma granarium, Sitophilus oryzae, S. granarius, Tribolium castaneum, T. confusum, Sitotroga cerealella, Callosobruchus chinesis, C. analis* and many others including rodents and birds (Ashfaq *et al.,* 2001). The Khapra Beetle *(Trogoderma granarium* Evarts.), is one of the world's most dreaded pests of whole and ground cereals, oilseeds, maltings, copra and other foodstuffs. Its great economic importance is due to its capability to cause huge loss in stored grains through voracious feeding and heating of grains, in larval ability to withstand starvation for up to 3 years as well as in its ability to live on food with very low moisture content. Banks (1977) confirmed that that *T. granarium* is one of the most serious pests in hot, dry conditions such as the Sahel region of Africa and parts of the Indian sub-continent. Studies have further revealed that the pest is extremely cold-hardy and tolerant of both high temperature and extremely low relative humidity. Rees, (1998) reported that larvae as well as adults of *T. granarium* are similar in appearance to *T. variabile* but *T. granarium* is better able to survive and breed on cereals and cereal products. Devastating infestations can occur, especially in bag stored grain and seed stores. Pruthi and Singh (1950) reported that Khapra beetle is primarily a pest of stored grains Howe, 1952 revealed that Larvae wander in and out of sacked material, weakening the sacks, which may ultimately tear. Rahman *et al*. (1945) observed that feeding by khapra beetle larvae reduces the weight and grade of grain. The loss of grain or costs of necessary treatment may result in less profit for wholesalers. The world economic losses caused by this pest ranged 2-70 % but estimates of storage losses of food grains due to insects have been reported to vary greatly; 10-18% (Hafiz and Hussain, 1961), 2.32% in Pakistan (Khan and Cheema, 1978), about 7.0 to 22.0 % (Girish *et al.,* 1975), 3.40 to 6.53% in India (Khan and Kulachi, 2002).

Qualitative losses, food safety and the khapra beetele

Cast skins may cause dermatitis (Pruthi and Singh, 1950), barbed hairs of larvae that rub off and remain in the grain may present a serious health hazard if swallowed (Morison, 1925). Diekmann (1996) indicated that more than 20 different species of storage pests are found in cereal grains including *T. granarium* which has been declared as a quarantine pest in most of the countries of the world. Perez *et al*. (2003) also reported that insect fragments in commercial wheat flour are a major concern to the milling industry because consumers expect high quality and wholesome products at the retail level. Parashar (2006) reported that *T. granarium* larvae are one of the most serious stored seed pest but the beetle itself does not damages. The larvae starts feeding from embryo point and later consume the entire kernel/seed which makes the grain hollow and only the husk remains. Infested seeds are full with frass, cast skins of larvae and excreta, which results in deterioration of quality of pulses. The larvae are often found on edges of jute sacks and make the infested store unhygienic. There is an increasing trend among grain buyers towards zero-tolerance to these contaminants. Jood and Kapoor (1992) reported that protein and starch digestibility of wheat, maize and sorghum having 25, 50 and 75% grain infestation caused by *T. granarium* and *R. dominica* separately and in mixed form were affected significantly ($P<0.05$) and adversely. However, a 25% level of grain infestation did not affect the parameters significantly (Jood and Kapoor, 1992). Further experiments conducted by Jood and Kapoor (1993); Jood *et al*. (1993, 1996a) revealed that severe infestation of stored grains by *T. granarium* may make the grains unpalatable or unmarketable. Grain quality may decrease due to depletion of specific nutrients. Infestation levels of 75% in wheat, maize, and sorghum grains resulted in significant decreases in crude fat, total carbohydrates, sugars, protein nitrogen, and true protein contents and increases in moisture, crude fiber, and total protein. Jood *et al*. (1993) used two major pests of stored cereals in tropical and subtropical regions of Asia and Africa, *R. dominica* and *T. granarium*, in experiments to investigate the effect of insect infestation on organoleptic characteristics of stored cereals. 'Chapatis' made from infested and uninfested grain flours were evaluated for colour, taste, texture, aroma and appearance by a panel of semi-trained judges. There were no significant differences in the scores for colour, appearance, aroma and texture at all infestation levels for all three cereal grains and the scores also did not differ significantly from uninfested grains. However, at 50 and 75% infestation levels, scores for the taste of Chapatis of three cereal grains were significantly ($P < 0.05$) lower than uninfested grains. Bitter taste also resulted in poor overall acceptability of Chapatis prepared from flours infested at the 50 and 75% levels. Besides, substantial losses of the vitamins thiamin, riboflavin, niacin (Jood and Kapoor, 1994), essential amino acids (Jood *et al*., 1995) and starch contents (Jood *et al*., 1993) also occurred at infestation levels of 25% and above. While working on protein contents of cereals, there were significant increases for non-protein nitrogen, total nitrogen, total protein, uric acid (Jood and Kapoor, 1993), the anti-nutrient phytic acid and anti-nutrient polyphenol (Jood *et al*., 1995) at infestation levels of 25% and higher. Jood *et al*. (1996b) also concluded that levels of uric acid were above acceptable limits for food consumption at 50% and 75% infestation levels. Total lipids, phospholipids, galactolipids, and polar and nonpolar lipids all declined significantly at infestation levels of 50% and 75%. Some workers have reported that dietary preferences of *T. granarium* vary not only from commodity to commodity but also vary within different varieties of the same commodity. Poplawska *et al.* (2001) carried out investigations on feeding preferences of the khapra beetle towards some plant products. The pest showed more feeding preferences to buckwheat products, grits and meal to barley grain.

Sayed *et al*. (2006) performed experiments to determine varietal resistance of wheat against *T. granarium* and *R. dominica* from Pakistan. For this purpose they used twelve wheat varieties grown in Sindh province. Their results revealed that population build up in both insect treatments was the lowest in variety Mehran-89, whereas, the highest population was recorded in the variety, TJ-0787. On the basis of percent grain weight loss, the most resistant variety to both insect species was found to be the Mehran-89, while the least resistant varieties recorded were, TJ-0787 and Sarsabz.

Integrated pest management and the khapra beetle

According to Ahmad (1994) grain storage management is as important a field as grain production itself, but unfortunately it has remained badly ignored in the past in Pakistan. Eradication of khapra beetle has been reported as difficult, which may reduce its susceptibility to some control methods (Table 2), so control methods designed to eradicate new infestations must be able to penetrate throughout the infested material or facilities (PASEK, 2004).

Table 2. Integrated pest management and the khapra beetle

Treatments	Options	Remarks
Dusting	Hydrophobic amorphous silica dust and fine sand	For small storage facilities (Kroschel and Koch, 1996)
Insecticide Dust	Chlorpyriphos-methyl, primiphos-methyl, parathyroids, malathion	Control of khapra beetle infestations in structures and surrounding surface areas (Rai *et al*., 1987; PASEK, 2004)
CO_2	Any source of CO_2	For small storage facilities (Krishnamurthy *et al*., 1993; Hodges and Surendro, 1996)
Fumigation	Phosphine (PH_3), Methyl bromide	For large scale post-harvest practice (Mueller, 1994; Rangaswami and Gunasekaran, 1996; Bell *et al*., 1996)
Exposure to sunlight	Dark paper and black polythene sheet	Quite effective against stored grains insect pest (Lale and Sastawa, 1996; Songa and Rono, 1998)
Control by drying	Bush dryer, solar dryer, light fire underneath crop	Temperature upto 85^o can not affect seed germination (Ntoukam *et al*., 1997)
Heat treatment	Treatment involves a 30-minute exposure at 60^{o}C	100% control of all stages of the khapra beetle (Battu *et al*., 1975; Ismail *et al*., 1988; PASEK, 2004)
Use of botanicals	Over 120 plants and plant products including garlic, caster, neem kernels, sweet flag rhizomes, mint leaves, ginger, garlic, lemon leaves etc.	Effective and cheap method to control the pest in stored wheat (Singh and Kataria, 1986; Mahgoub and Ahmad, 1996; Dales, 1996; Pal *et al*., 1996)
Treatment with fast electrons	Use a linear accelerator	An efficient method of controlling khapra beetle in store grain (PASEK, 2004).
Candidate alternatives	lowering the ambient humidity, entoleters, physical barriers, trapping, pheromones, food attractants, growth regulators, predators and parasites, space treatments with contact pesticides, residual treatment	Dobie, 1984; Annis and Waterford, 1996; MBTOC, 1998

RECOMMENDATIONS

Following recommendations have been suggested from the above study to overcome the problem of this pest in Pakistan.

1. No doubt, phosphine is an effective tool but lack of education and proper training and extensive use is leading towards its ineffectiveness. So there is need for proper education, training and use of integrated approaches both chemical as well as non-chemical control methods to over come this pest.

2. The toxicity of a large number of plant extracts has been checked against stored-product insects pests, over 120 plants and plant products have been used for the control of stored product insect pests (Dales, 1996). So botanicals may be used to overcome the problem of resistance in khapra beetle.

3. Facilities that can not be fumigated may be sanitized and treated with a surface application of insecticide or botanicals such as malathion should be applied repeatedly for control of khapra beetle infestations in structures and surrounding surface areas (PASEK, 2004).

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