IRRADIATION OF KHAPRA BEETLE AS A QUARANTINE ALTERNATIVE TO METHYL BROMIDE FUMIGATION

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The khapra beetle, *Trogoderma granarium* Everts, is the most serious quarantine pest of dry stored food commodities such as grain, tree nuts, peanuts and farinaceous commodities. The khapra beetle is quarantined from many countries where it does not occur including the United States, the former Soviet Union, and Australia. Jute, burlap bags, and other packing materials are commonly infested with the khapra beetle if they originate in a country where the khapra beetle is present. Many agricultural commodities have been found upon inspection to harbor the khapra beetle. In the U.S. the only approved quarantine treatment for the khapra beetle is fumigation of the infested commodity with methyl bromide at the port of entry. Other fumigants and insecticidal treatments do not appear to offer any significant hope of replacing methyl bromide for quarantine purposes. The primary reason for this pessimism is the unusual tolerance of the khapra beetle, especially the diapausing larvae, to many insecticides. Even other fumigants and high CO_2 atmospheres are not particularly effective against this species, and the development of resistance to phosphine fumigation has been documented in the khapra beetle. Irradiation offers one possible alternative quarantine treatment for the khapra beetle that should now be seriously considered.

Irradiation has several advantages over fumigation as a quarantine treatment, some of which are general in nature and some of which are peculiar to the khapra beetle. The major advantage of irradiation over fumigation is that a lethal dose can usually be delivered in minutes, or at most an hour or two, depending on the type, size, and configuration of the irradiator and the dose rate. Thus, most suspect cargoes probably could be irradiated during the unloading process. No comprehensive study of the radiosensitivity of the khapra beetle has been published. The information on radiosensitivity of this species is widely scattered and is collated here for the first time.

The first brief report on radiosensitivity of this species was published almost 40 years ago. Since then the radiosensitivity of each stage has been reported, with several different ages of some stages studied. A comprehensive picture of the radiosensitivity of this species can now be compiled showing it to be relatively susceptible to irradiation in comparison to other stored-product pests. Irradiation effects on khapra beetle eggs

have been reported by several authors and a similar pattern of sensitivity was reported. Younger eggs are more radiosensitive than older eggs, and in general eggs are more sensitive than the other stages. Figure 1 shows the lethal dose for older eggs to be 100 gray, but although eggs hatch when exposed to lower doses they do not develop successfully after exposure to ca. 30 gray. The radiosensitivity of khapra beetle larvae has been studied extensively and these studies showed that young larvae are more sensitive than older larvae (Table 1). First instar larvae were killed by only 50-60 gray, and third instar larvae by 50-100 gray. Fifth instar larvae required doses of up to 250 gray for complete larval mortality. Mature larvae required high doses to prevent pupation, and prepupae required a dose of 1.02 kgray to kill 50% of them before pupation. About 50% of the fifth instar larvae treated with 50 gray became adults (the highest dose that allowed adult formation.) These emergent adults were sterile even at this low dose. Significantly, diapausing larvae were as susceptible as non-diapausing larvae to irradiation when mortality or prevention of pupation was the criterion.

Three separate studies showed that khapra beetle pupae were rendered sterile by low to moderate doses of 60-190 gray. Females (paired with untreated males) were sterilized by 60-75 gray, and males (paired with untreated females) were sterilized by 150-190 gray. No comprehensive study has been published on the radiosensitivity of adults. An early report of recently emerged adults irradiated with a series of 3 doses (50, 100, and 150 gray), stated that females were sterilized by 50 gray but males were not quite sterile after 150 gray (8 offspring from 30 males). No studies of older adults or adults already mated when irradiated have been published. These adults might be somewhat more resistant than young adults to the sterilizing effects of radiation. However, earlier ARS studies showed the differences between young and old adults were not great in other species of *Trogoderma*, and that these species were very sensitive to irradiation sterilization in comparison to other species of stored-product pests.

Though no comprehensive study of radiosensitivity of the khapra beetle has been reported, enough studies are available that taken as a whole, a reliable pattern of sensitivity to irradiation in comparison to other stored-commodity pests emerges. This conclusion is bolstered by the fairly complete studies of several other species in the genus *Trogoderma* that show this group of insects are among the most sensitive beetles to irradiation known. The promise that irradiation holds as a potential quarantine treatment for the khapra beetle indicates that a study designed specifically to determine an acceptable dose of irradiation for quarantine purposes is urgently needed.

Fig. 1. Relationship between egg age and percentage egg hatch at two doses of gamma irradiation in the khapra beetle (drawn using the data of Ahmed, 1975).

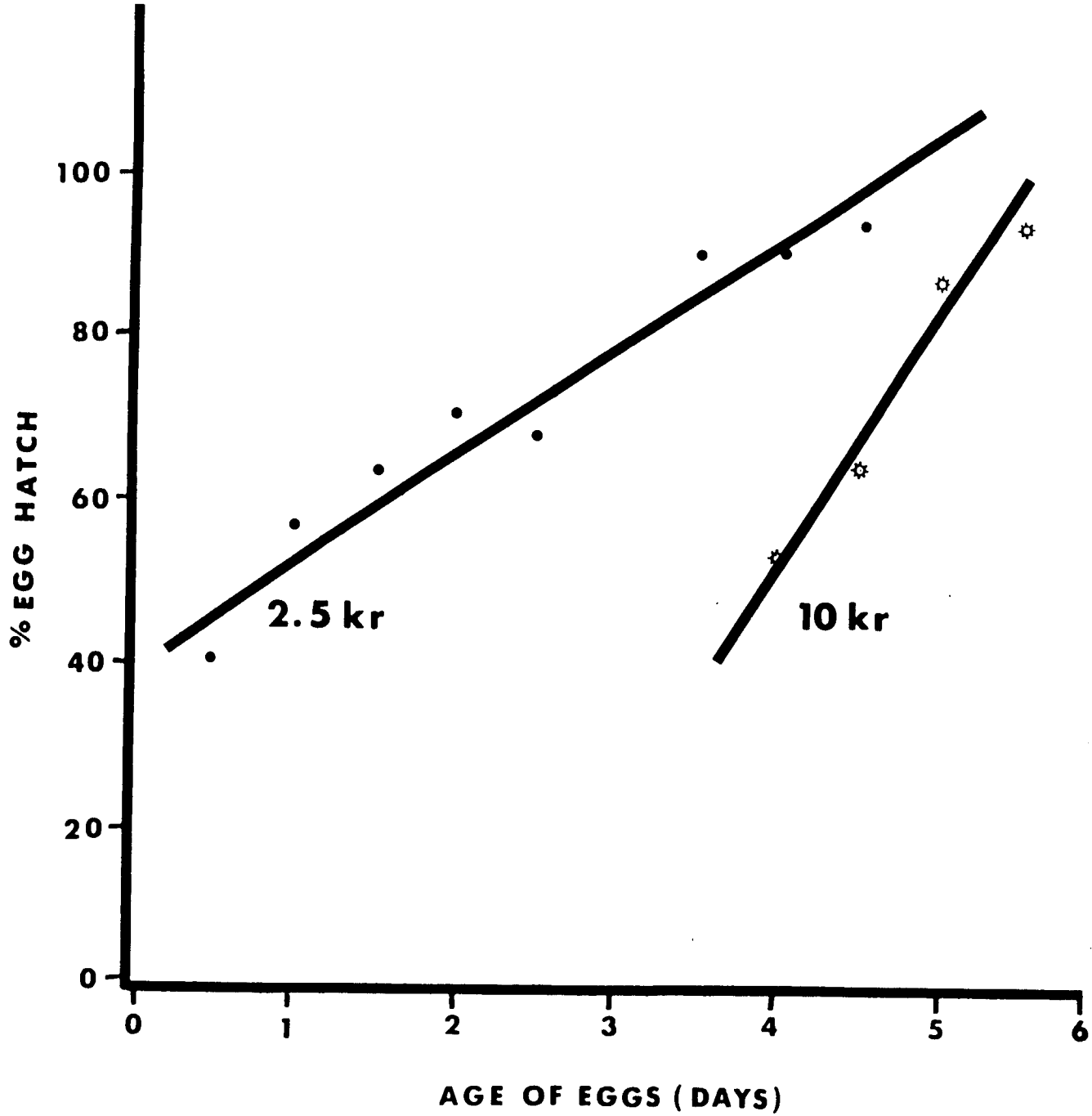

Table 1. Lethal and sterilizing doses for larvae and pupae of *Trogoderma granarium* of various ages

Stage and age	Lethal dose	Sterilizing dose	Reference
Larvae			
1st instar	5 kr	--	Ahmed & Iqbal 1982
1st instar	6 krad	--	Nair & Rahalkar 1963
2nd instar	10 kr	--	Ahmed & Iqbal 1982
3rd instar	5 kr	--	Huque 1963
3rd & 4th instar	10 kr	--	Ahmed & Iqbal 1982
5th instar*	15 kr	--	Ahmed & Iqbal 1982
5th instar*	25 kr	--	Ahmed & Iqbal 1982
Prepupae	>101 krad	--	Nair & Rahalkar 1963
Pupae			
1-2 day	>40 krad	♀ - 6 krad ♂ - 18 krad	El-Kady et al. 1980
1-4 day	--	♀ - 6 krad ♂ - 16 krad	Nair & Rahalkar 1963
4 day	120 krad	♀ - 6 krad ♂ - 19 krad	El-Kady et al. 1980
4 day	--	♀ - 7.5 krad ♂ - 15 krad	Ahmed & Ahmed 1981

* Fifth instar larvae 12 hrs and 36-60 hrs after moulting, respectively.