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Effect of non-ionizing radiation (UVC) on the development of *Trogoderma granarium* Everts

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Abstract

Various instars of khapra beetle *Trogoderma granarium* were exposed to ultra-violet rays (UVC) to assess their effect on each instar and their potential in breaking the developmental cycle of the khapra beetle.

Eggs aged zero (recently laid), 24 and 48 h were exposed to UVC at a radiation intensity of $31.4 \pm 0.02\,W\,m^{-2}$. Doses equivalent to 3 min ($56.52\,J\,cm^{-2}$), 8 min ($150.72\,J\,cm^{-2}$), and 12 min ($226.08\,J\,cm^{-2}$) resulted in death of all eggs, with a hatch of 96.6% in the control.

Mortality of UVC-irradiated larvae increased proportionally with increase in UVC dose, while, for each dose, mortality was inversely related to age of larvae at irradiation. Thus, at a UVC dose of $56.52\,J\,cm^{-2}$, larval mortality was 98.3%, 93.3% and 83.3% and adult emergence was 1.7%, 6.7% and 11.7% for 1–9, 10–18 and 19–27 day-old larvae, respectively. Similar effects were observed for UVC doses 150.72 and $226.08\,J\,cm^{-2}$ with an increase in the overall mortality of larvae and a decrease in adult emergence. Effect of irradiation of 0, 24 and 48 h-old pupae with doses of UVC, was inversely related to age of pupae at irradiation. Thus, at $56.52\,J\,cm^{-2}$, mortality as pupae was 91.7%, 71.7% and 73.3% and adult emergence was 0%, 3.3% and 1.7% for 0, 24 and 48 h-old pupae, respectively. Premature emergence of deformed adultoids was 25% when 24 and 48 h-old pupae were irradiated with the above dose. At a dose of 225.08 $52\,J\,cm^{-2}$ there was no adult emergence. Death as pupae was 98.3%, 96.7% and 78.3% and premature emergence was 1.7%, 3.3%, and 21.7% for pupae irradiated at 0, 24 and 48 h-old, respectively.

Keywords: *Trogoderma granarium*; Susceptibility; Ultra-violet radiation

1. Introduction

Trogoderma granarium Everts is one of the most serious pests of grain in storage facilities in the tropics and subtropics (Banks, 1977; Bell et al., 1983; Szlendak and Davis, 1989) and is common in geographical areas characterized by high temperature and low humidity (Howe and Lindgren, 1957). It is present in Syria and the prevailing climatic conditions in the area are conducive to serious outbreaks.

There are various methods for the control of *T. granarium*. Fumigation is one of these methods. Phosphine is a very toxic fumigant that is used at low concentrations, penetrates well and produces few residues. However, it requires a long exposure time, is not effective at low temperatures and, most importantly, resistance to phosphine has been reported in *T. granarium* (Borah and Schalal, 1979) and other storage pests (Tyler et al., 1983). For many years methyl bromide was an effective fumigant against many pests and for many applications. Its ability to penetrate deep into commodities and structures, its effectiveness at low concentrations and rapid effect on pests have made it the method of choice for many applications. However, its potential for depletion of the ozone layer has compelled the parties to the Montreal Protocol to agree to phase methyl bromide out by 2010 in developed countries, and to freeze its consumption and production, and finally to phase it out by 2015 in developing countries (Clarks, 1998). Conventional pesticides

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have been commonly used for controlling *T. granarium*. However, over the years, the species has become tolerant to most of these pesticides and fumigants (Banks, 1977; Bell et al., 1983). Controlled-atmosphere treatment is another method that is used occasionally to control stored-product insects. Williams et al. (1980) found when using nitrogen (N_2) atmospheres that the durations of exposures required to kill the eggs, larvae, pupae, and adults of maize weevils were 4.0, 7.5, 8.0 and 3.0 days, respectively, while 5 days exposure killed all larvae of khapra beetle. Other methods of control use ionizing irradiation from gamma or fast-electron sources. These methods are recognized for insect pests in grain stores (FDA, 1981). A number of pilot plants have been used world wide (Aoki et al., 1977), but they require a sophisticated infrastructure, shielding and do not provide any long lasting protection. In the present study, non-ionizing radiation, i.e. ultra-violet radiation (UVC), was used as a possible method for controlling *T. granarium*. To apply this method, it is essential to investigate the effect of different intensities of UVC radiation on different life stages of the insect. A search of databases for research on UVC and *T. granarium* did not yield any information on minimum radiation doses for suppressing infestation. Therefore, we have chosen radiation doses arbitrarily to evaluate the effect of UVC doses on the developmental stages of *T. granarium*.

2. Materials and methods

2.1. Insects

All insects used in our experiments were taken from a *T. granarium* stock culture reared on pesticide-free wheat grains in 3-l glass jars covered with mesh. Cultures were kept in continuous darkness at a temperature of $31 \pm 4\,^{\circ}C$ and at 30–50% r.h. Insects used in experiments were kept in an incubator in continuous darkness at a temperature of $31 \pm 1\,^{\circ}C$.

For different age larvae and pupae, eggs were allowed to hatch and newly hatched larvae were designated "1-day old". Larvae were tested at ages of 1–9 days, 10–18 days, and 19–27 days. Newly-formed pupae were designated the age "0" h and pupae were tested at 0, 24 and 48 h.

2.2. UVC radiation source

The UVC radiation source was a low-pressure Hg lamp 60 cm in length (UVC Long Life, TUV 15W G 15 T8, Philips). This lamp produced UVC at a wave length of 253.7 nm. The shorter, and ozone-forming wave length of 185 nm was filtered out by the special glass tubing of the lamp (Philips web page, www.philips.com, last visited on 3 November 2006) which was fixed inside a locally-designed irradiation cabinet ($50 \times 50 \times 30$ cm). The cabinet was made of stainless steel, with the front cover made of glass. The lamp was fixed to the inner side of the cabinet roof. The exposure stage was fixed 5 cm from the surface of the UV lamp. Radiation intensity was measured at a fixed point on the exposure stage using a radiometer (UVX Digital radiometer E18054, UVP Inc., Upland, CA, USA). Radiation intensity was determined to be $31.4 \pm 0.02\,W\,m^{-2}$. The total UV dose was determined from the measured radiation intensity multiplied by the time of exposure. The temperature inside the UVC cabinet was not measured but the cabinet was placed in a laboratory where the room temperature was $24 \pm 1\,^{\circ}C$. During irradiation, the insects were left at room temperature in daylight.

2.3. Experiments with eggs

One-day–old virgin male and female adults were obtained by isolating male and female pupae from the stock culture. Male and female adults were allowed to mate by pairing them inside a Petri dish in an incubator. Eggs were collected using a fine brush and those destined for irradiation were placed together in a test tube cap. Eggs treated within the first three hours of laying were designated the age "0". Eggs were irradiated at 0, 24 and 48 h after laying. Three replicates were used for each treatment, with twenty eggs/replicate. Similar number of replicates and insects per replicate were used for the controls. Control eggs were placed in the irradiation chamber for the designated time without being exposed to UVC. The following doses of UVC were used: $56.52\,J\,cm^{-2}$ (equivalent to 3 min exposure), $150.72\,J\,cm^{-2}$ (equivalent to 8 min exposure), and $226.08\,J\,cm^{-2}$ (equivalent to 12 min exposure). After irradiation eggs were returned to their corresponding Petri dishes. Numbers of hatching eggs were scored every day for a week.

2.4. Experiments with larvae

Larvae chosen for irradiation were of three different ages: 1–9, 9–18 and 18–27 days old plus the control. Using soft forceps, larvae of similar age were isolated into four different groups, one for the control and three for the different doses. Each group consisted of three replicates, with 20 insects/replicate. Larvae in each replicate were exposed simultaneously to the designated UVC dose by placing these larvae in a plastic screw cap. Each treatment group was exposed to one of three doses of UVC, namely, $56.52\,J\,cm^{-2}$ (exposure time 3 min), $150.72\,J\,cm^{-2}$ (exposure time 8 min), and $226.08\,J\,cm^{-2}$ (exposure time 12 min). After exposure to UVC, irradiated larvae were returned to their corresponding Petri dish and provided with wheat and cracked wheat grain as food. All irradiated and control larvae were returned to the incubator under the conditions described in Section 2.1. Development of larvae was followed until the end of their life cycle. Time between selecting and grouping the larvae and returning them to the incubator after irradiation was never more than 2 h.