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BRIEF NOTE

BEHAVIORAL RESPONSES OF *DERMESTES VULPINUS* TO *GAMMA* RADIATION[1]

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Constantly increasing human populations have focused the attention of many biologists on the problem of preservation of stored grains. The losses of stored products in the U.S. caused by insect pests were found to be well over a billion dollars in 1956 (Hassett). On a world wide basis, Munro (1966) reported that pests of stored grain destroy 10% to 40% of the production, depending on the crop and location. This finding has led a number of researchers to explore the use of radioactivity to sterilize grain (see Brower 1975 for a summary). An even larger literature describes the reduction or elimination of pest populations by competitive mating of males sterilized by radioactivity. Radioactive chemicals also have been used to tag insects in research testing dispersal (O'Brien and Wolfe 1964). On the other hand, scant attention has been paid to the behavior of irradiated insects. Schurr (1969) and Schurr (1971) describe a rapid increase in activity of *Tribolium castaneum* and *Dermestes vulpinus* when exposed to γ radiation. Of other authors, only Smith *et al* (1963) have touched on this subject—and then tangentially—by their experiments with 12 species of cutworm moths that exhibited motor activity in response to low level X-ray exposure.

The goal of the present research was to determine if γ radiation would change the membranes on delicate microsensillae after radiation. Augenstein *et al* (1964) describe leakage of enzymes from cell membranes after irradiation. Roth and Eichel (1955) document about 30% loss of catalase through cell membranes within minutes of exposure to X-rays. Michelson (1977) has shown changes of myoblast cells after γ radiation, presumably because of loss of cell membrane integrity. In addition, Catravas and Weiss (1979) describe changes in membranes due to radiation. There was sufficient evidence from these studies and from the work of Borg and Norris (1971) to expect that changes in behavior and fine structure could be correlated.

Dermestes vulpinus were removed from our lab culture as pupae. Three to eight days after they metamorphosed to adults they were used in this study. The radiation source was a Picker Nuclear Model 547 Cesium[137] facility. We conducted all tests in a lead-shielded room with a temperature of 23 °C ± 1 and RH of 31% ± 3. Pictures of insect microsensillae were taken with a Hitachi HHS-2R scanning electron microscope, and activity was recorded with a Hildebrant 320-G solid state transducer and a Tektronix 125 Servo/Riter as described by Schurr (1971). Tests of activity were alternated in time, but paired, meeting the statistical assumptions of the Sign Test employed.

We found no changes in any of the sensillae of *Dermestes vulpinus* no matter what dosage of radiation was given the animals. Increased activity persisted in insects after irradiation however, suggesting that irritation resulted from the radiation and required a passage of time to subside. In support of this idea, the results of the second part of the study were significant.

Dermestids were divided into groups of ten, exposed to 800 r. After one hr delay, the activity of the ten animals was measured with a solid state crystal

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transducer and recorded by strip chart for 4 hr. Nonirradiated control groups were tested between experimental groups. We alternated our measurement so that experimental animals were tested on the morning of one day and the afternoon of the next. The clear top of the test chamber allowed observation. This insect species is thigmotactic and will crowd in groups at the angles of the chamber. Comparative activity was measured by counting the spikes (traced by the strip chart pen) which were over one cm in height. The device could measure intensity of activity, so the data document running rather than walking (table 1).

TABLE 1

Movements by individuals in groups of 10 Dermestes vulpinus.

800 r Irr. No. moves/4 hr	Nonirr. No. moves/4 hr*
56	8
37	9
42	16
48	5
25	4
61	11
39	5
51	5
59	9
30	6

*Significant difference ($P<0.05$, Sign Test).

A continuation of increased activity by *Dermestes vulpinus* occurred after gamma radiation. Unexpectedly, we observed mating in both experimental and control groups. This increased activity seems to be an increase in irritability rather than aberrant behavior. Both groups moved into corners and clumped as a result of thigmotactic reactions; both groups displayed sexual behavior. Those animals exposed to radioactivity were much more active in a generalized way.

Since an increase in the insect's reaction is noted with a wet diet (Schurr 1971), this finding suggests that radicals and reactive chemicals are formed by radiation in the hemolymph and cells as is typical for the radiochemistry of water (Allen 1961). Recent findings indicate that univalent reduction of O_2 takes place, meaning that super-oxide radicals ($O_2\overline{\cdot}$) and hydroxyl radicals ($OH\cdot$) are intermediates. Furthermore, $O_2\overline{\cdot}$ can act both as a reductant and an oxidant, producing an array of substances and radicals capable of destructive effects in living cells (Fridovich 1975). Collodial cell elements accept the radicals, so a permanent change takes place and a state of equilibrium is not reached as in the case of pure water (Dertinger and Jung 1970).

Change can be shown by electronic spin resonance signals (ESR) after radiation. The ESR changes in various studies are discussed by Muller (1967) and Evans (1979). Krebs and Benson (1965) used γ radiation of moderate levels on ants and then tested the electronic spin resonances. They found an increase in the signal for free radicals and a slow decay with time after irradiation.

Michelson (1977) states that cell injury is due to the carbonate anion radical, $CO_3\overline{\cdot}$, in the presence of $HO\cdot$, hydroxyl radicals, with photoactivation of the reaction. Superoxides and peroxides are not the cause according to his data, narrowing down the possible reasons for the behavior response to gamma radiation observed in our study. Brown (1966) reported that ant colonies exposed to gamma radiation built tunnels where they foraged in radioactive areas. The same ants behaved normally while searching for food in areas not exposed to radiation. Considering all these bits of evidence together with my observations and results, the most logical explanation for the behavioral response observed is $CO_3\overline{\cdot}$ and $HO\cdot$ radicals, which cause irritation by attacking unsaturated lipid components of nerve membranes, in the presence of light, by oxidative carboxylation. Of course, there may be loss of superoxide dismutases from cells in this event and thus superoxides may also be a factor.

I suggest that these radicals affect membranes of nerve tissue, so that an irritation results. Insects do not sense gamma radiation as some might suggest (Callahan 1965); they feel the damaging side effects. During an interval needed for repair of membranes and recovery of protective enzymes, above normal activity will persist, representing the first explanation for the behavior response of increased activity and increased dispersal in insects following exposure to radioactivity. The successful movement of stored product pests through a maze so they might avoid gamma radiation, as well as the extreme activity of populations of insects trying to disperse from a gamma radiation field (Schurr 1971), bring into question the wisdom of using radiation for sterilization of stored products. Hassett (1956) has calculated costs as low as 94¢ / ton of grain for gamma radiation sterilization of insect pests. No physical or chemical damage would affect the grain; however, it is likely that conveyor belt systems for grain transport through the irradiation chamber would simply result in the wholesale dispersal of insect pests through the grain storage facility. Rather than sterilization of the stored grain, it is probable that an increased number of infested bins would result.

A positive aspect of this line of study should be the use of stored products insects to examine the effects of free radicals generated by gamma radiation and their interactions on the chemistry on biological membranes. It is also likely that the success of male insect sterilization with radioactivity and subsequent mating in competition with wild males has benefitted from the behavioral response described. On the other hand, I suggest that no useful information can be derived from studies using radioactive tagging of insects to test dispersal. The irritation would make dispersal activity quite exaggerated.

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