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The Effect of ^{137}Cs Radiation on Growth, Development, and Mortality of the Larvae of the Tussock Moth, *Hemerocampa leucostigma*[1]

H. W. ROSSMOORE AND E. A. HOFFMAN

Department of Biology, Wayne State University, Detroit, Michigan 48202

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Larvae and pupae of *Hemerocampa leucostigma* were irradiated in a ^{137}Cs Radcell and observed for effects on growth, development, and mortality. Irradiated larvae were half of control weight 10 days postradiation. Although pupae were extremely resistant, relatively low doses to larvae prevented emergence. LD_{100} of first instars was 30 kr, while that of third instars was 85 kr. No delay in median time to pupation was noted.

INTRODUCTION

The relative resistance of insects to ionizing radiations is by now well documented (O'Brien and Wolfe, 1964; IAEA, 1967, 1968). Despite this resistance, the utility of ionizing radiation for insect control has been proven with radiation-sterilized males and in deinfestation of stored grain. However, this investigation was undertaken neither to add radiation resistance data on still one more species nor to suggest radiation as a tool for control of the tussock moth larvae, but rather to establish baseline dosages for examining a problem of fundamental importance: the effect of radiation on the immune response. This will be reported in a subsequent paper.

MATERIALS AND METHODS

Larvae of *Hemerocampa leucostigma* were maintained and raised on maple leaves as previously described (Rossmoore et al., 1970). Radiation was carried out in the center well of a ^{137}Cs Radcell (U. S. Nuclear Corporation, Model GR-6A) at a dose rate of 10 kr/hr. To offset any effect of confinement during long-term radiation, controls were kept in similar containers in an incubator maintained at the internal temperature of the radiation chamber.

Animals were irradiated during first and third instar and also shortly after pupation. Larvae were observed for growth as determined by weight and cephalometry, time to pupation, gross anomalies, and mortality (prior to pupation—larval death and lack of emergence—pupal death). Pupae were observed only for mortality.

RESULTS AND DISCUSSION

Despite the fact that irradiated larvae appeared obviously smaller than control

TABLE 1

CEPHALIC CAPSULE MEASUREMENT[a] OF *Hemerocampa leucostigma* LARVAE[b] FOLLOWING ^{137}CS RADIATION

Radiation dose (kr)	Cephalic capsule size (mm)					
	3rd Instar		4th Instar		5th Instar	
	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$	$\bar{x}$	$S_{\bar{x}}$
0	1.10	0.11	1.59	0.11	2.14	0.16
40	1.10	0.06	1.59	0.15	2.13	0.14

[a] Measurements made using stage micrometer, unit = 0.075 mm (sizes given are $\bar{x}$ of 100 larvae).
[b] All larvae were irradiated in early third instar.

[1] Contribution No. 262, Department of Biology.

TABLE 2

THE EFFECT OF ^{137}Cs RADIATION ON WEIGHT GAIN OF *Hemerocampa leucostigma* LARVAE[a]

Group	Days between weighings	Weight gain (mg)	
		Radiation dose 0 kr	Radiation dose 30 kr
A[b]	8	57.45	28.15
B	10	108.34	50.82
C	9	98.76	44.08
D	10	94.35	48.25
E	10	107.77	36.74
		$\bar{x}$ $S_{\bar{x}}$	$\bar{x}$ $S_{\bar{x}}$
		93.34 ± 11.6	41.6 ± 8.4

[a] All animals were irradiated in early third instar.

[b] Each group contained 10 controls and 10 irradiated larvae. Each 10 were weighed together. Weights given are the averages per larva.

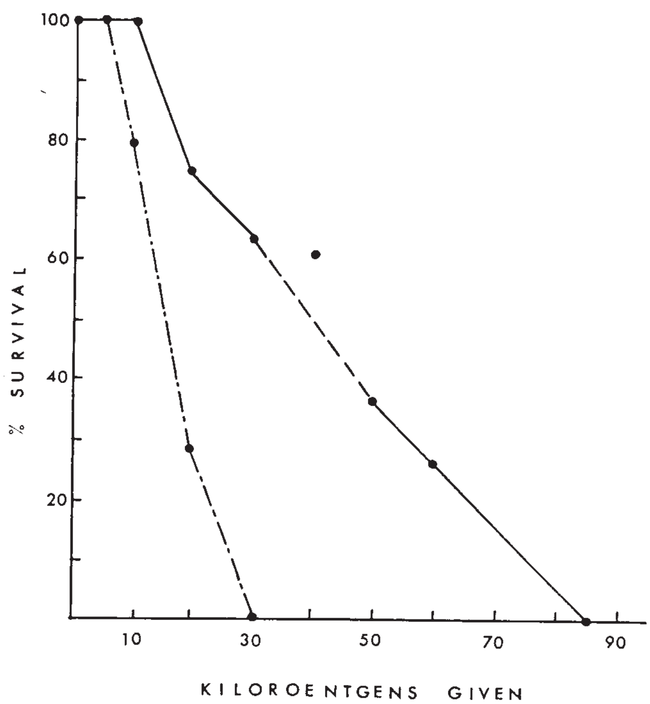

FIG. 1. The effect of ^{137}Cs radiation on survival of *Hemerocampa leucostigma* larvae. Survivors are animals that at least pupate but may or may not emerge. — · — · — ·, First instar larvae; ————, third instar larvae.

animals, there were no detectable differences in sizes of head capsules shed in successive molts (Table 1). This was true for doses up to 40 kr. At higher doses, larval death before pupation prevented collection of sufficient capsules for significant evaluation.

In contrast to lack of differences in cephalometry, irradiated animals weighed

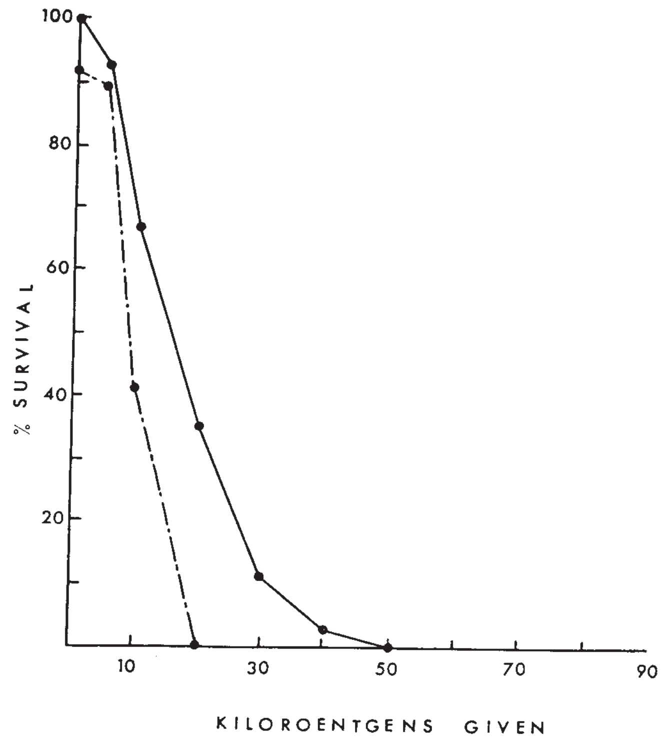

FIG. 2. The effect of ^{137}Cs on survival of *Hemerocampa leucostigma* pupae irradiated as larvae. Survivors are animals that at least emerged. — · — · — ·, Pupae from first instar larvae; ————, pupae from third instar larvae.

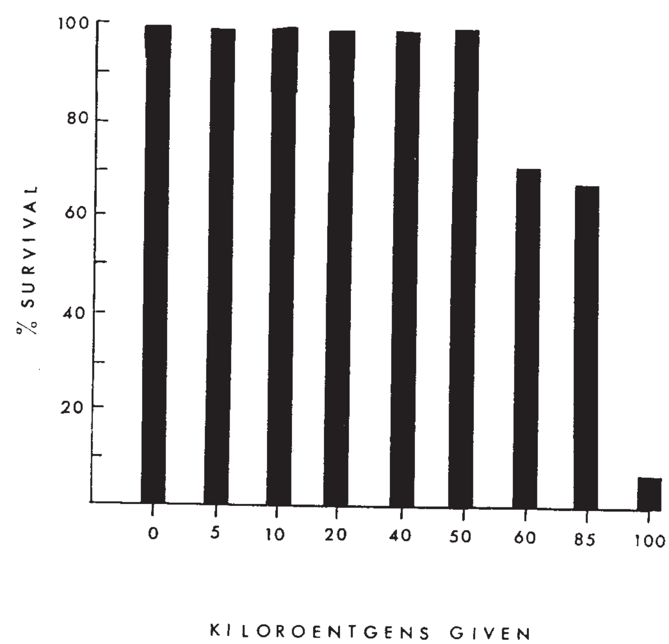

FIG. 3. The effect of ^{137}Cs on survival of *Hemerocampa leucostigma* pupae irradiated as pupae. Survivors are animals that at least emerged.

only half of their control counterparts 10 days after 30 kr (Table 2). This weight differential is probably not due to lower intake of food, although the appetites of irradiated animals were reduced. It may be due to poorer absorption of nutrients or loss of water from the gut. There is ample evidence for this phenomenon in mammals, and we have preliminary histological evidence that radiation does disrupt gut wall integrity. The effects of radiation on larval mortality (Fig. 1) indicate that first instar larvae are much more sensitive than third instar larvae. This increase in radioresistance with increasing larval age has been demon-

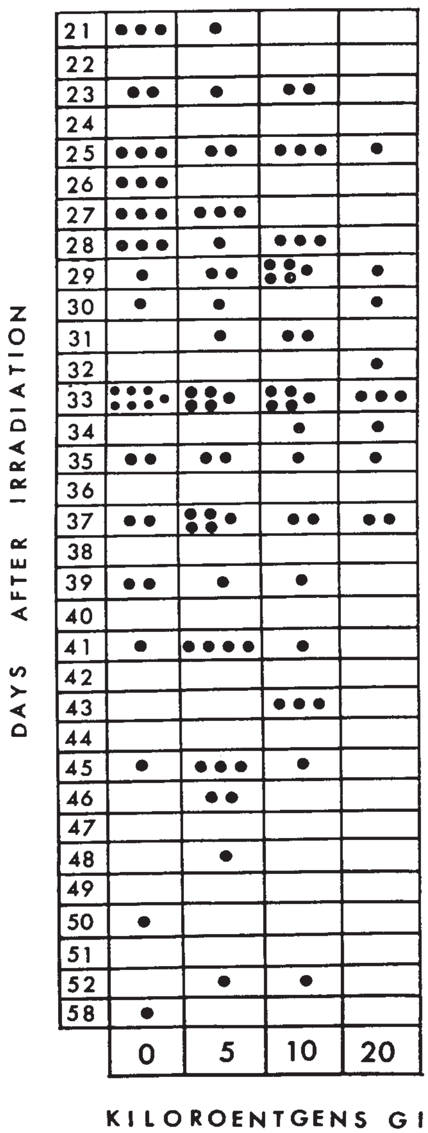

FIG. 4. Pupation time of first instar *Hemerocampa leucostigma* larvae following ^{137}Cs radiation. Each ● represents the pupation of one larva.

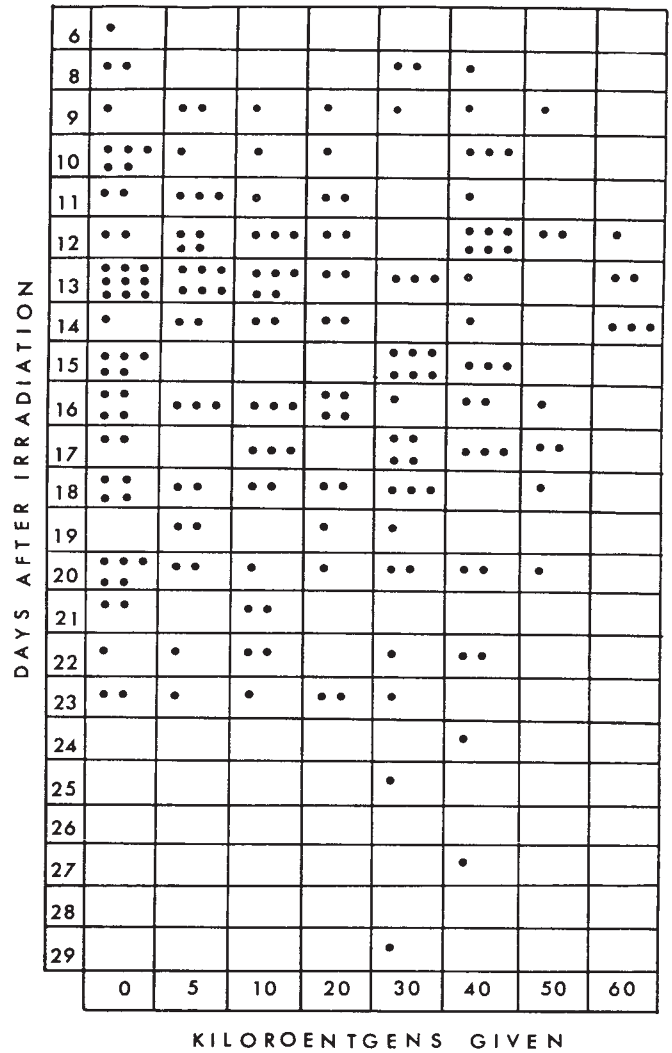

FIG. 5. Pupation time of third instar *Hemerocampa leucostigma* larvae following ^{137}Cs radiation. Each ● represents the pupation of one larva.

strated previously with *Porthetria dispar* (Godwin et al., 1964) and maintains the rule of thumb that radiation sensitivity is directly proportional to length of dividing future, and inversely proportional to the degree of cellular differentiation.

A comparison of pupal survival resulting from larval radiation (Fig. 2) with that from direct pupal irradiation (Fig. 3) reiterates that more advanced morphogenetic forms are more radioresistant. It also emphasizes (Fig. 2) that control of pupal development is affected very early in larval life and is apparently more radiosensitive than are the larvae. This apparent sensitivity, however, was not reflected in any significant delay in average time to pupation following larval irradiation (Figs. 4, 5). The median pupation time for first instar larvae was 29 days; whereas, the time for animals receiving 5, 10, and 20 kr was 34, 31, and 33 days. The data for the irradiated third instar larvae showed that median pupation time varied from 14 to 16 days.

Thus irradiation seemed to have no effect on the morphogenetic timetable of most animals. Even those doses which produced significant larval mortality before pupation did not affect survivor pupation time. During this study, a very small number of larvae never pupated or suffered radiation death. This number was less than 1% and occurred at all radiation doses. Another infrequent (<1%) occurrence is shown in Fig. 6. This "two-headed" caterpillar resulted from 60 kr but was also seen after 30 kr. The inability to shed the old cephalic capsule might be related to a lack of a specific enzyme concerned with molting. Although not as dramatic as "two heads," animals were also seen dragging their old integuments after them. This too was an infrequent event.

There were few surprises in these results. Radiation resistance increases with age and with advance in developmental stage as previously noted (O'Brien and Wolfe, 1964).

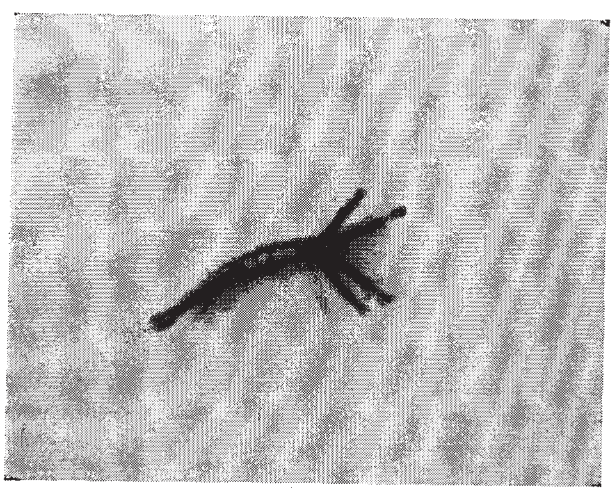

FIG. 6. Loss of molting ability in fourth instar larva of *Hemerocampa leucostigma* following 60-kiloroentgens of ^{137}Cs radiation.

The radiation dose required for larval extinction is of the same order of magnitude as *Malacosoma americanum*, a member of the Lasiocampidae (Smirnoff, 1967) but approximately four times higher than that for *P. dispar* (Godwin et al., 1964), a member with *H. leucostigma* of the Lymantriidae. Failure of radiation to alter the developmental process measured by time between molts (size of cephalic capsule at molt) and median time to pupation is unusual.

Earlier studies with *Anagasta kuhniella* (Whiting, 1950) and *Rhodnius prolixius* (Baldwin and Shaver, 1964), two quite different species, demonstrated definite delays in time to pupation with lower doses. The very small number of total anomalies we observed, e.g., "two-headedness" and infinite larval life, might be related to the lack of significant effect on the developmental timetable. Perhaps, the time during instars at which differentiation activity is most expressive is also the radiosensitive peak. We have tried to confine all radiation to the period immediately following molt. Until we irradiate this species over a broader temporal spectrum, we will not be able to fully assess the diminished responsiveness of these larvae to ionizing radiation.

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