Detection of irradiated insect pests in stored products: locomotor activity of irradiated adult beetles

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Abstract

The aim of this study was to develop an indirect behavioural test (locomotion as a measure of vigour) to detect irradiated insects. It was noted that the higher the dose applied, the lower the locomotor activity of treated beetle pests of stored products. For radiation disinfestation, doses ranging from 0.3 to 1.0 kGy are suggested. At these doses, the walking speed of insects, i.e., ability to disperse, is greatly affected.

Different species responded to gamma irradiation in different ways. At the 1st day post-treatment, all *Tribolium confusum* Duv. beetles treated with 0.25–0.5 kGy doses exhibited a reduction in locomotor activity of more than 25%. The walking speed of the granary weevil, *Sitophilus granarius* (L.), and the bean weevil, *Acanthoscelides obtectus* (Say), treated with low doses of gamma radiation was not affected, or was higher than in controls. At subsequent days post-treatment, the walking speed of irradiated insects was negatively correlated with the dose applied.

Using data on the percentage of *T. confusum* that moved outside a 20 cm diameter circle during the first and subsequent minutes, it was possible to discriminate between insects irradiated with high doses of gamma radiation and those treated with 0.25 and 0.5 kGy, or untreated. The results suggest that the locomotor test may be used to detect irradiated stored product pests. The causes of decreased locomotor activity and/or ability to disperse have not been yet established. However, muscles controlling locomotion (walking) seem to be damaged by radiation.

Introduction

The ability to disperse is an indicator of the physiological condition of irradiated insects. Usually the propensity to fly and duration of each flight is decreased in irradiated insects. Males and females of the Mediterranean fruit fly irradiated with 0.1 kGy were 40 and 60%, respectively, less active than the native flies (Schroeder et al. 1973). Irradiation causes in some insects the general syndrome that Grosch (1956) called 'irradiation induced lethargy'. He reported that irradiated *Bracon hebetor* (Say) lost all interest in feeding and instead remained in approximately the same position for days.

Locomotor activity of irradiated insects seems also to be decreased by the irradiation treatment. *Dacus cucumis* French fruit flies showed decreased locomotor activity which declined progressively at 0.4, 0.6 and 0.8 kGy (Bailey 1975). However, no special research has been undertaken to determine the effects of ionising radiation on locomotor activity of stored product pests.

In general, a dose of 0.5 kGy is suggested for radiation disinfestation of agricultural products infested by stored product pests (Tilton and Burditt 1983). At this dosage, adult survivors of pests will be present in the treated commodities, but they will not give rise to offspring, and thus this pest would not be able to establish in a new area (storehouse). The live insects present in the agricultural products will nevertheless be of concern to quarantine and/or storage personnel.

Thus, investigations are needed to determine if techniques can be developed to demonstrate that surviving pests have been irradiated and are unable to reproduce (Burditt 1992).

Wiygul and Haynes (1974) developed a locomotor test for the prediction of the degree of sterility in chemosterilant-treated boll weevils, *Anthonomus grandis grandis* Boheman. They found a negative correlation between locomotor activity and the percent sterility in the boll weevils resulting from feeding 0.9% busulfan in the diet for 6 days. Baumhover (1965) and Ignatowicz (1990) used female mortality to measure the sexual aggressiveness of sterilised adult males of screwworms (*Cochliomyia hominivorax* Coq.) and mould mites (*Tyrophagus putrescentiae* (Schrank)), respectively.

The aim of the present study was to develop an indirect behavioural test (test of locomotion as a measure of vigour) to determine if insects have been subjected to irradiation.

Material and Methods

The following stored-product pests were studied: *Tribolium confusum* Duv., *Sitophilus granarius* (L.), *S. oryzae* (L.), and *Acanthoscelides obtectus* (Say). The insects were from laboratory cultures on wheat grain or beans at ca. 70% r.h. and 25°C in darkness.

Adult beetles isolated from the cultures were irradiated with the following doses of gamma radiation: 0.0 (control), 0.25 kGy, 0.5 kGy, 1.0 kGy, and 1.5 kGy. Treated insects were stored for 1, 3 and 5 days in darkness at 25 ± 1°C and 70% r.h. After these periods, adult beetles were isolated and placed separately into 4 round cages (3 cm diameter) kept in red light under the Panasonic CCTV (model WV-CD 22) video camera. Movements of four insects during 5 minutes were tape recorded with Time Lapse video recorder (AG-6020). There were 4 replicates of each test (16 insects per treatment). Recorded locomotory activity was then transformed numerically using a program created for the Macintosh® computer, and the mean walking speed (relative units per secund) of treated insects was determined.

Additional locomotory tests were conducted as outlined by Wiygul and Haynes (1974). For each test, a piece of paper (ca. 25 × 35 cm) was prepared with 2.5 and 20 cm diameter circles drawn in the centre. Then a small plastic funnel was placed in the 2.5 cm diameter circle, and ten adults of the confused flour beetle, *T. confusum*, were placed in the funnel. Two minutes later (period of orientation) the funnel was removed, and the beetles were allowed to crawl for 1–5 minutes. A count was then taken of the insects that had crawled out of the 20 cm

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diameter circle. The procedure was replicated three times for a complete test. The score was computed as the percentage of beetles that moved out of the 20 cm diameter circle during the test period.

Results

Results on the effects of gamma radiation on walking speed of adult beetles, pests of stored products are presented in Figures 1–4.

One day after irradiation, the locomotor activities of confused flour beetles, *T. confusum*, treated with 0.25–1.5 kGy of gamma radiation, were similar, but 26–40% less than in the control. At the 3rd day post-treatment, it was found that the walking speed of treated beetles decreased as the dose of irradiation increased. A dose of 0.25 kGy decreased the locomotor activity of the confused flour beetle by 34%, while a dose of 1.5 kGy by ca. 72%. At the 5th day post-treatment all beetles treated with 1.0–1.5 kGy of gamma radiation were not moving. Those beetles treated with 0.25–0.5 kGy doses exhibited a reduction in locomotor activity by 50–60% (Table 1, Figure 1).

The walking speed of the granary weevils, *S. granarius*, treated with low doses (0.25–0.5 kGy) of gamma radiation was not affected. Higher doses, however, reduced the locomotor activity considerably. Three days after irradiation, the walking speed of 1.0 and 1.5 kGy treated insects was reduced by ca. 40 and 80%, respectively. At the 5th day post-treatment, the locomotor activity of the granary weevils irradi-

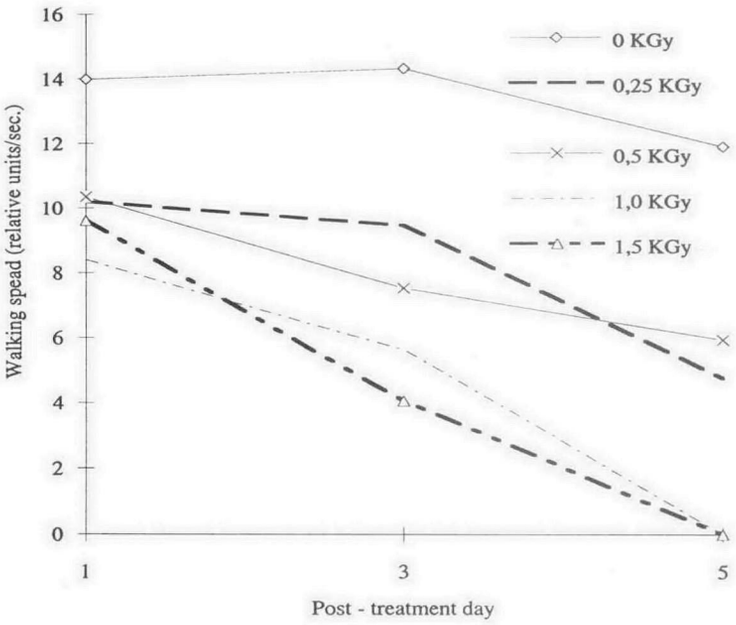

Fig. 1. Locomotor activity (walking speed) of adults of the confused flour beetle, *Tribolium confusum* irradiated with 0.25–1.5 kGy doses of gamma radiation. —◇— 0 kGy; — — — 0.25 kGy; —×— 0.5 kGy; —•—•—• 1.0 kGy; and —△ 1.5 kGy.

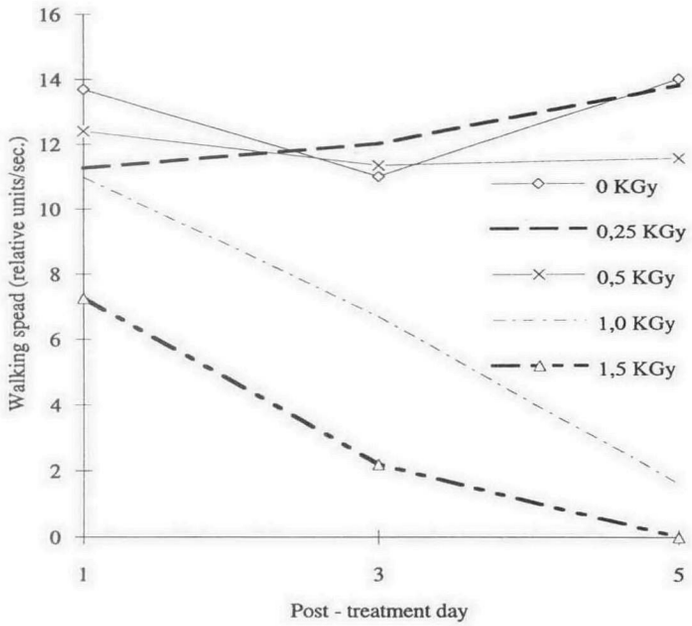

Fig. 2. Locomotor activity (walking speed) of adults of the grain weevil, *Sitophilus granarius* irradiated with 0.25–1.5 kGy doses of gamma radiation. —◇— 0 kGy; — — — 0.25 kGy; —×— 0.5 kGy; —•—•—• 1.0 kGy; and —△ 1.5 kGy.

Table 1. Locomotor activity of irradiated stored product beetles (relative units per second).

Species	Day post-treatment	Dose (kGy)				
		0	0.25	0.5	1.0	1.5
Tribolium confusum	1	13.98	10.20	10.34	8.40	9.60
	3	14.33	9.46	7.53	5.63	4.06
	5	11.91	4.76	5.94	0.00	0.00
Sitophilus granarius	1	13.70	11.26	12.41	10.97	7.26
	3	11.00	12.01	11.34	6.69	2.19
	5	14.03	13.81	11.58	1.63	0.00
Sitophilus oryzae	1	12.48	12.71	10.62	8.99	4.03
	3	13.41	9.81	5.65	0.00	0.00
	5	13.24	13.69	0.00	0.00	0.00
Acanthoscelides obtectus	1	5.63	7.12	5.79	2.21	1.82
	3	7.96	2.12	3.52	1.42	0.00
	5	3.62	1.46	1.58	0.00	0.00

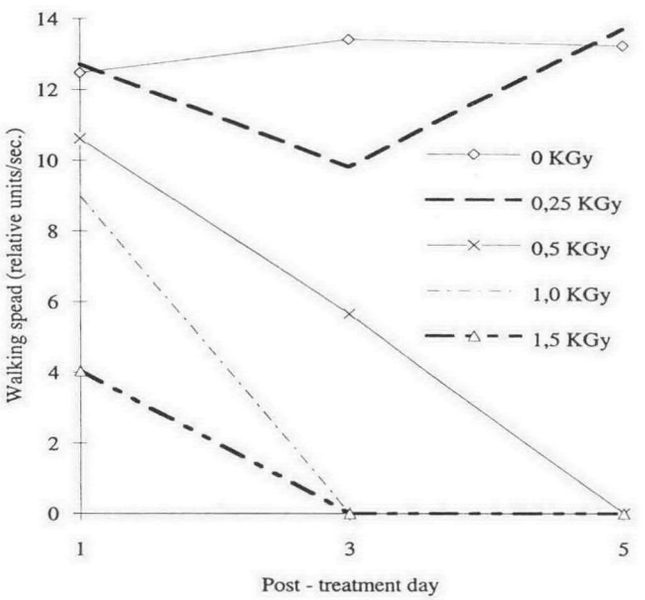

Fig. 3. Locomotor activity (walking speed) of adults of the rice weevil, *Sitophilus granarius* irradiated with 0.25–1.5 kGy doses of gamma radiation. —◇— 0 kGy; — — — 0.25 kGy; —×— 0.5 kGy; —•—•—• 1.0 kGy; and —△ 1.5 kGy.

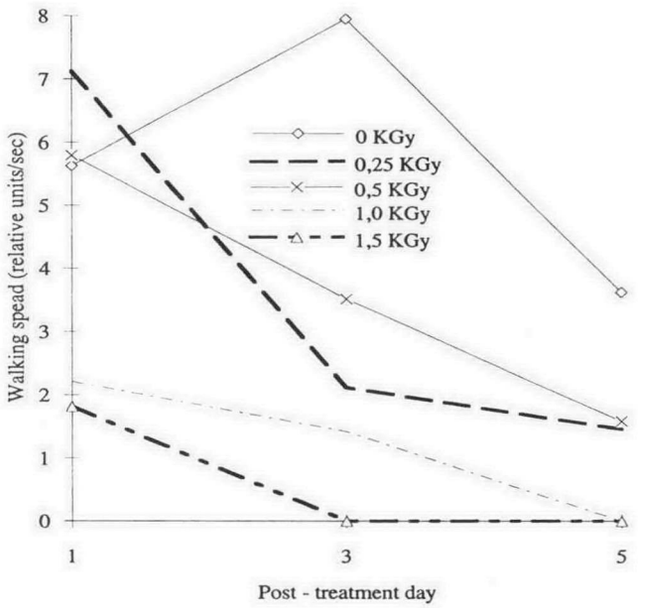

Fig. 4. Locomotor activity (walking speed) of adults of the bean weevil, *Acanthoscelides obtectus*, irradiated with 0.25–1.5 kGy doses of gamma radiation. —◇— 0 kGy; — — — 0.25 kGy; —×— 0.5 kGy; —•—•—• 1.0 kGy; and —△ 1.5 kGy.

ated with 1.0 kGy was reduced by 88.4% as compared with the control. All beetles treated with a dose of 1.5 kGy were dead or not moving (Table 1, Figure 2).

A related species, the rice weevil, *S. oryzae*, responded to irradiation in a different way. At the 1st day after the treatment, the walking speed of the control and 0.25 kGy-treated weevils was similar. The higher doses of gamma radiation significantly reduced the locomotor activity of treated insects. The rice weevils irradiated with 1.0 and 1.5 kGy were 28 and 67.7%, respectively, less active than the control insects. The higher the dose applied, the lower the locomotor activity of treated weevils. At the 3rd day post-treatment, the walking speed of 0.25 kGy-treated weevils was lowered by 26.9%, but at the 5th day it was similar to the control. The locomotor activity of the rice weevil treated with 0.5 kGy was lowered by 57.9% at the 3rd day post-treatment. All weevils treated with 1.0 and 1.5 kGy were dead or not moving at the 3rd day post-treatment, and those treated with 1.0 kGy had died at the 5th day (Table 1, Figure 3).

At the 1st day post-treatment, the locomotor activity of the bean weevil, *A. obtectus*, treated with 0.25 and 0.5 kGy was similar or higher than the control, while it was significantly reduced by 1.0 and 1.5 kGy doses (by 60.7 and 67.7%, respectively, as compared with the control). At the 3rd and 5th day after irradiation, the walking speed of the bean weevil was much more affected by the irradiation treatment than at the 1st day, and was negatively correlated with the dose applied (Table 1, Figure 4).

Results of the locomotor tests with the confused flour beetle, *T. confusum*, are presented in Figures 5-9. It was found that high doses of gamma radiation significantly affect the locomotor activity of tested insects as compared with the control. Using data on the percentage of insects that moved outside the 20 cm diameter circle during the first and subsequent minutes, it was possible to discriminate the insects irradiated with high doses (0.75 and 1.0 kGy) of gamma radiation from those treated with 0.25 and 0.5 kGy and untreated.

Discussion

The ability to fly and disperse from release sites has been investigated extensively in irradiated insects for the sterile insect release technique (SIRT) needs. The SIRT requires that the mass cultured and irradiated insects should exhibit similar vigour as native. In contrast, the locomotor activities (walking) and dispersal of stored-product pests irradiated with sublethal and/or sterilising doses have received a little attention. However, it is important to know how pests respond, in terms of locomotory activity, to radiation doses recommended for disinfestation.

It was noted that the higher the dose applied, the lesser the locomotory activity of treated beetles. For radiation disinfestation, stored-products doses ranging from 0.3 to 1.0 kGy are suggested. At these doses, the walking speed of insects, i.e., ability to disperse is greatly affected.

The various species responded to irradiation in a different way. At the 1st day post-treatment, all *T. confusum* beetles treated with 0.25–0.5 kGy doses exhibited a reduction in locomotory activity of more than 25%. The walking speed of the granary weevil and the bean weevil treated with low doses of gamma radiation was not reduced. At the next days post-treatment, the walking speed of irradiated insects was negatively correlated with the dose applied. Because of this, it is possible to use the locomotor test proposed by Wiygul and Haynes (1974) for identification of irradiated insects. This test was used by them to determine the degree of sterility among chemosterilant-treated male boll weevils.

Using data on the percentage of the confused flour beetles that moved outside a 20 cm diameter circle during the first and subsequent minutes, it was possible to discriminate the insects irradiated with higher doses of gamma radiation from those treated with 0.25 and 0.5 kGy, or untreated. Thus, the locomotory test may be used as a means of discriminating irradiated insect pests of stored products.

The specific causes of decreased locomotor activity and/or ability to disperse in irradiated insects have not yet been estab-

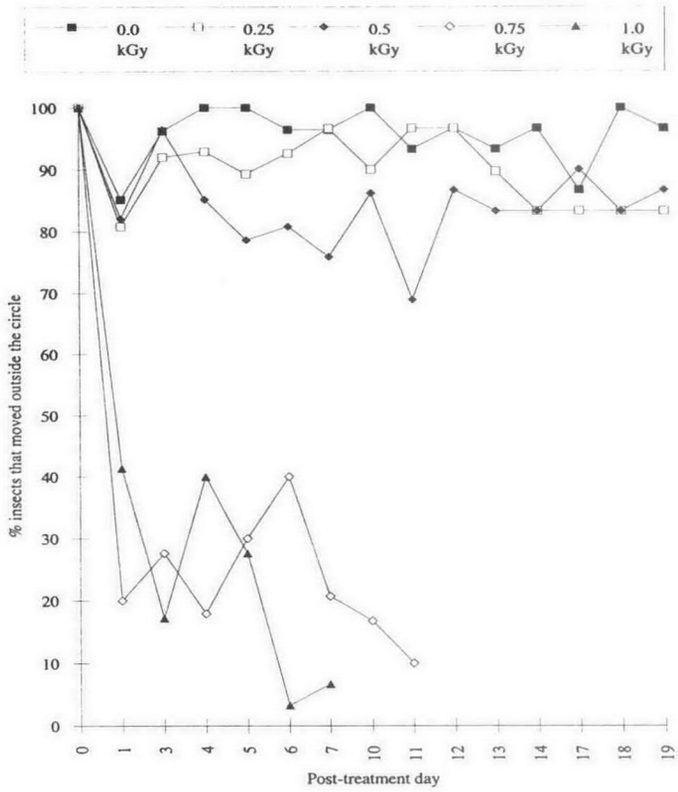

Fig. 5. Percent of *T. confusum* beetles that moved outside the circle after 1 minute.

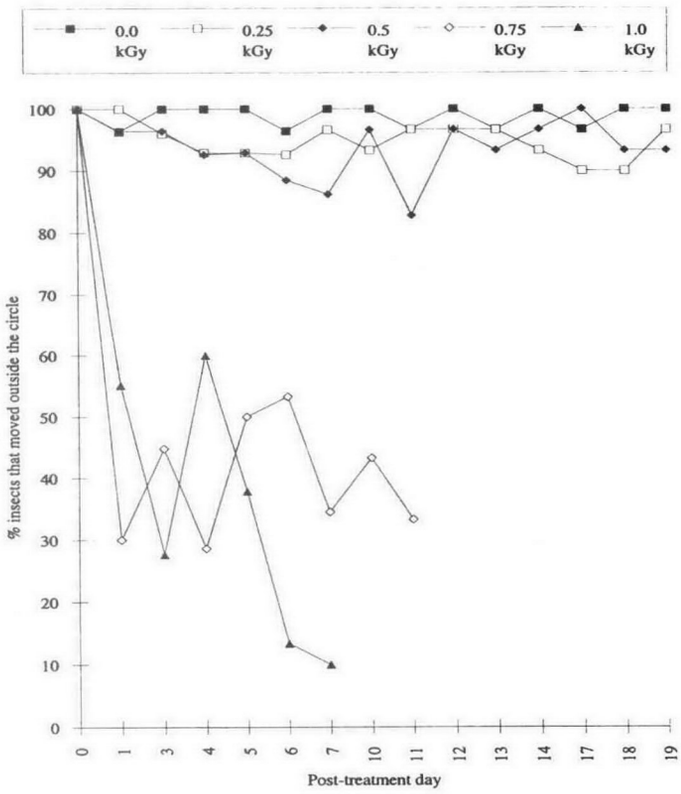

Fig. 6. Percent of *T. confusum* beetles that moved outside the circle after 2 minutes.

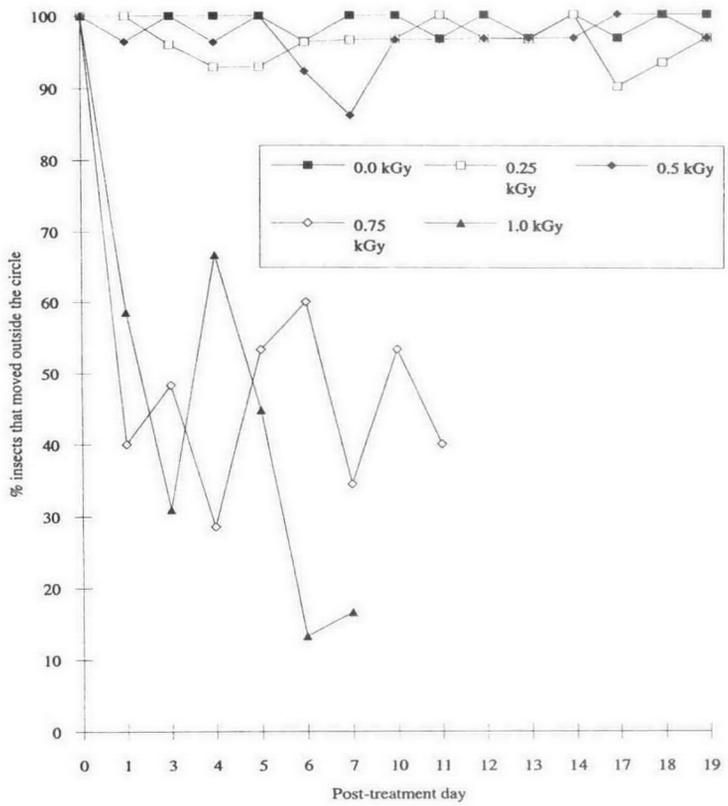

Fig. 7. Percent of *T. confusum* beetles that moved outside the circle after 3 minutes.

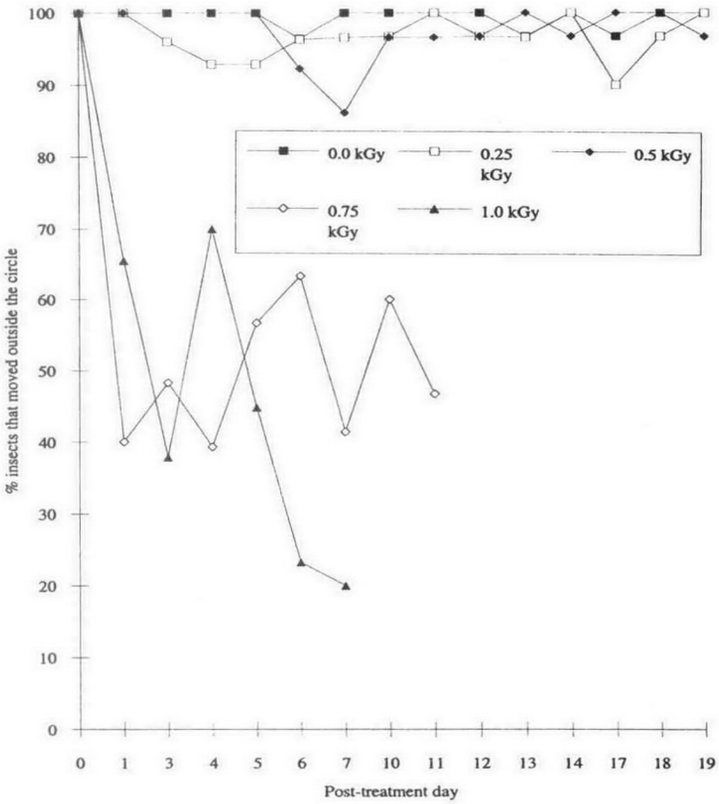

Fig. 8. Percent of *T. confusum* beetles that moved outside the circle after 4 minutes.

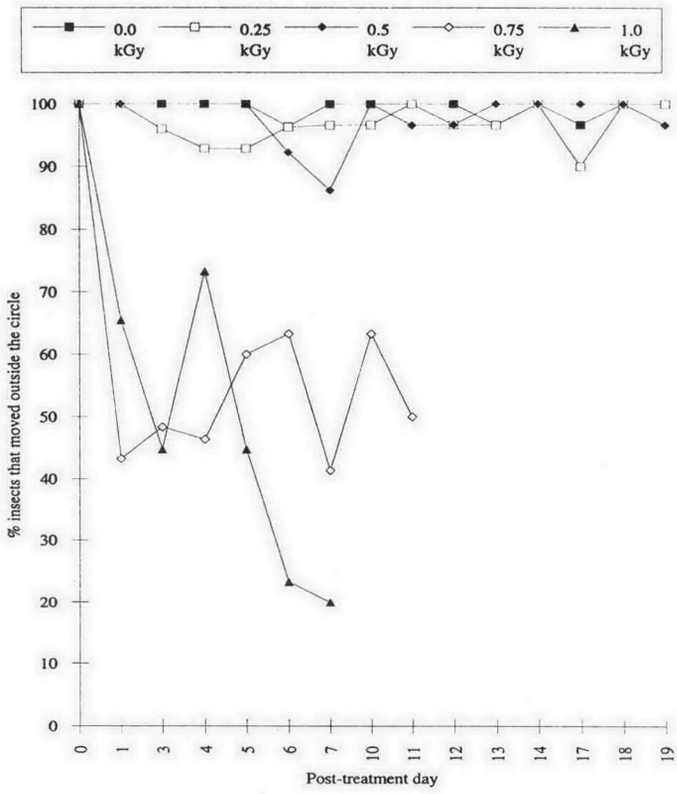

Fig. 9. Percent of *T. confusum* beetles that moved outside the circle after 5 minutes.

lished. Lack of dispersal or decreased ability to disperse in irradiated insects may result from a decreased locomotor and flight ability. Several workers have proposed that reduced flight in irradiated insects may result from damage to muscle tissue, especially the flight muscles, by relatively low doses (Bhakthan and Nair 1972; Nair and Bhakthan 1969). Muscles controlling locomotion (walking) seem to be damaged by radiation as well.

Disease and malnutrition also may have an effect on the vigour of adult beetles, and these factors should be considered when using the locomotion test for identification of irradiated insects.

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