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Gamma Irradiation as an Alternative Treatment for Controlling of *Lyctus africanus* Lesne (Coleoptera: Bostrichidae) in Dry Wood

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ABSTRACT

The present study was carried to determine the efficacy of gamma radiation on different developmental stages of the powder post beetles, *Lyctus africanus* Lesne (Coleoptera: Bostrichidae). The lethal dose of gamma radiation for larvae, pupae, and adults was determined. Mortality following irradiation of larvae was significantly high at all doses of irradiation. No adults emerged from larvae irradiated at 80 and 100Gy. On the other hand, the losses in wood weight decreased with increasing gamma doses. Irradiated pupae with all radiation doses (20 to 100Gy) had no effect on adult emergence. Exposing pupae to different gamma irradiation doses (20 up to 100Gy) showed morphological changes. Adults of *L. africanus* irradiated with the doses of 120 and 140Gy died soon after emergence.

Key words: *Lyctus africanus*; dry wood; gamma radiation; lethal dose.

INTRODUCTION

Wood is one of the oldest materials used for making tools, utensils, shelter, ships and vehicles. It soon became apparent that wood is susceptible to the effects of fire, weathering, and various organisms (insects, fungi, and bacteria). Coleopterons wood-boring beetles play an important role not only in Egypt but also all over the world because they comprise the most important groups of injurious insect pest. *Lyctus africanus* Lesne (Coleoptera: Bostrichidae) is considered a serious pest of wooden article, furniture and wooden floors…etc., where the powder post beetles spend their larval stage slowly boring through wood. The true powder post beetles earned their common name from the very fine powdery frass found in their tunnels. Lyctine beetles, also known as lyctid beetles, are second only to termites in their destruction of structural wood. They are serious pests of hardwoods, mainly ash, hickory, oak, maple and mahogany (Brammer, 2013). Powder post beetle is a term used to describe several species of small wood-boring insects (1/8-3/4 inches long) which reduce wood to a fine, flour-like powder. Damage is done by the larvae as they create narrow, meandering tunnels in wood as they feed. Infestations are discovered after noticing small, round "shot holes" in the wood surface. These are exit holes where adult beetles have chewed out the wood after completing their development. Lyctid powder post beetles attack only wood products manufactured from hardwoods. Consequently, infestations are most often found in wood paneling, molding, window and door frames, plywood, hardwood floors and furniture.

Gamma radiation, as a high energy, ionizing electromagnetic radiation, easily penetrates through wooden objects. It is known to be very effective in the context of disinfestation of wooden artifacts (Katušin-Ražem *et al.*, 2009 and Fairand and Ražem, 2010) but also for wood sterilization (Freitag and Morrell, 1998; Pratt *et al.*, 1999 and Severiano *et al.*, 2010). In contrary to alpha and beta rays, which penetrate only very thin layers, gamma radiation fully penetrates wooden objects (Tišler and Medved, 1997). The energy-rich gamma rays modify molecular structures and lead to unexpected function of living cells or to their death. Methyl bromide is the most widely used fumigant for logs but does have some limitations, *i.e.* limited penetration, particularly across the grain and into wet timber. Most arthropods associated with timber are susceptible to methyl bromide (Rhatigan *et al.*, 1998). Some alternative methods showed efficiency in controlling pests such as ionizing radiation (Lorini and Beckel, 2002). Due to need for better conservation and control of insects with modern technology, advanced high-efficiency, low cost and absence of side effects, the gamma radiation has become the most viable solution. This process inhibited reproduction, or even causing the death of the infesting insects (Ramos *et al.*, 2009). Moreover, gamma irradiation was suggested as a treatment for wood and wood products (Reichmuth, 2002).

Besides disinfestation prior to restoration, sterilization of wood is applied for testing the resistance of wood and wooden products against wood-destroying organisms. For both purposes restoration and resistance testing of gamma radiation is considered as a suitable decontamination method (Despot *et al.*, 2012).

The objective of this work is to study the effect of gamma radiation on the different developmental stages of *L. africanus* and determine the lethal dose for all stages.

MATERIALS AND METHODS

Rearing Technique

Pure culture of powder-post beetles, infested samples with *L. africanus* was provided by the laboratory of wood borers, Plant Protection Research Institute, Agricultural Research Center, Giza, Egypt. Blocks of Poinciana royal (***Delonix regia* Raf**.) wood sized (5cm long and 2cm diameter) were placed in plastic boxes (6 x 8cm). Five healthy and active pairs of newly emerged adults were placed into each box, and the boxes were kept in a dark room at 27±1ºC and 85±5% RH.

Irradiation technique

The irradiation technique was performed using Gamma Cell-40 (Cesium-137 Irradiation Unit), at National Center for Radiation Research and Technology (NCRRT). The dose rate was 0.714 rad / sec. at the tested time.

Experimental techniques

Larval experiments

Five pairs of newly emerged adults of *L. africanus* (one week old) were placed into a plastic box, contained a block of wood for each dose and replicate. The boxes were incubated until the females laid their eggs. After 24h of treatment, the adults were removed from the boxes. Two weeks later, the infested blocks of wood with newly hatched larvae were irradiated by five doses of gamma rays (20, 40, 60, 80 and 100Gy) and incubated until emergence of adults. The same trend was applied by full grown larvae (40 days from the removal of adults from wood) and incubated until adult emergence. Three replicates were used for each dose and control. Data were recorded and percentage of reduction in emerged adults was calculated. The blocks of Poinciana royal–wood were weighted without adults before irradiation and after adult emergence to calculate the loss percentage of wood caused by larvae feeding.

Pupal experiments

Full grown pupae of *L. africanus* (12 day old) were collected from the artificial diet made of wheat flour, yeast and water then air-dried (Helal, 1977). Full grown pupae were exposed to gamma irradiation using five dose levels ranging from 20 to 100Gy increments. Ten pupae used for experimental purposes were placed into a (1 x 3 inch) specimen glass tube covered with muslin and secured by rubber bands for each replicate. Three replicates were carried out for each dose and incubated until adult emergence under the controlled conditions of 27±1ºC and 85±5%RH.

Percentage reduction of *L. africanus* emerged adults that irradiated as larvae and pupae were calculated according to Abbott, (1925).

$$\% \text{ Reduction} = \frac{C - T}{C} \times 100$$

Where: C = mean number of emergence adults in the control. T = mean number of emergence adults in the treatment.

Adult experiments

Ten adults (one week old) were placed in plastic box with block of Poinciana royal-wood for each replicate. The boxes were irradiated with 50, 100, 150, 200 and 250Gy. Three replicates were used for each dose and control. Numbers of dead adults were counted daily.

Statistical analysis

Data were subjected to one ways ANOVA (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Effects of gamma radiation on *Lyctus africanus* irradiated larvae

Data presented in table (1) showed the effect of gamma radiation on newly hatched larvae of *L. africanus*. Infested wood blocks with newly hatched larvae were irradiated with 20, 40, 60, 80 and 100Gy. The first newly emerged adults occurred after 26 days of radiation treatment. Data showed that the highest mean numbers of adults' emergence (15.3 insects) occurred at the first week of inspection in control compared to 11.0, 7.6, 4.6, 3.0 and 1.0 insect, at the treatment doses of 20, 40, 60, 80 and 100Gy, respectively. Mean number of *L. africanus* emerged adults from newly hatched larvae irradiated with 20, 40, 60, 80 and 100Gy were 6.0, 4.3, 2.0, 1.3 and 0.0 insects, respectively comparing to 3.0 insects in the control at second week of inspection. For the third week, the mean number of adults' emergence was 2.6 insects in the control, while no adult emerged from all treatments. In other words, the total mean number of *L. africanus* adult emerged from irradiated newly hatched larvae decreased significantly from 24.3 insects in control to 17.0, 12.0, 6.6, 4.3 and 1.0 insects at the treatments of 20, 40, 60, 80 and 100Gy, respectively. Larval mortality significantly increased with the increase of gamma radiation doses which reflected eclosion of the powder post beetles. Reduction percentages of emerged adults from irradiated larvae with 20, 40, 60, 80 and 100Gy were 30.1, 50.6, 72.8, 82.3 and 95.9%, respectively.

Data in table (2) clearly showed that the higher dose of gamma radiation led to lower percentage of

Table (1) Mean numbers and reduction percentages of emerged *Lyctus africanus* adults irradiated as newly hatched larvae

Dose (Gy)	Mean No. of emerged adults			Total	% Reduction
	1st week	2nd week	3rd week		
Control	15.3±1.7	3.0±2.4	2.6±2.4	24.3±2.9[a]	-
20	11.0±1.6	6.0±2.0	0.0	17.0±1.6[b]	30.1
40	7.6±1.8	4.3±2.2	0.0	12.0±1.5[bc]	50.6
60	4.6±2.2	2.0±2.5	0.0	6.6±2.1[cd]	72.8
80	3.0±2.3	1.3±2.5	0.0	4.3±2.2[d]	82.3
100	1.0±2.5	0.0	0.0	1.0±2.5[d]	95.9

F value 13.61 L.S.D 5% 7.26

Table (2) Mean numbers and percentage reduction of emerged *Lyctus africanus* adults irradiated as full grown larvae

Dose (Gy)	Mean No, of emerged adults			Total	% Reduction
	1st week	2nd week	3rd week		
Control	15.3±1.7	3.0±2.4	2.6±2.4	24.3±2.9[a]	-
20	7.6±1.8	2.3±2.4	1.0±2.5	11.0±1.4[b]	54.7
40	3.3±2.3	0.3±2.6	1.0±2.5	4.6±2.2[bc]	81.1
60	0.6±2.6	0.6±2.6	0.0	1.3±2.5[c]	94.6
80	0.0	0.0	0.0	0.0	100
100	0.0	0.0	0.0	0.0	100

F value 20.08 L.S.D 5% 6.

Table (3): Percentage losses of irradiated wood infested with newly hatched larvae of *Lyctus africanus*

Dose (Gy)	Mean weight of wood before nutrition (gm)	Mean weight of wood after nutrition (gm)	Mean weight of consumed wood (gm)	% Loss of wood
Control	8.17±2.1	7.58±2.2	0.59[a]	7.2
20	6.27±2.0	6.03±2.1	0.24[b]	3.8
40	7.65±1.8	7.49±1.9	0.16[b]	2.1
60	6.48±1.9	6.29±1.9	0.19[b]	2.9
80	5.46±2.1	5.24±2.1	0.22[b]	4.1
100	7.67±1.8	7.54±1.8	0.13[b]	1.7

F value 13.33 L.S.D 5% 0.14

Table (4) Percentage loss of irradiated wood infested with full grown larvae of *Lyctus africanus*

Dose (Gy)	Mean weight of wood		Mean weight of consumed wood (gm)	% Loss of wood
	before nutrition (gm)	after nutrition (gm)		
Control	8.17±2.1	7.58±2.2	0.59[a]	7.2
20	6.51±2.0	6.26±2.0	0.25[bc]	3.8
40	10.25±2.2	9.96±2.2	0.29[b]	2.8
60	7.43±2.0	7.28±2.0	0.15[bcd]	2.0
80	7.21±1.8	7.14±1.9	0.07[d]	0.9
100	7.47±2.1	7.34±2.1	0.13[cd]	1.7

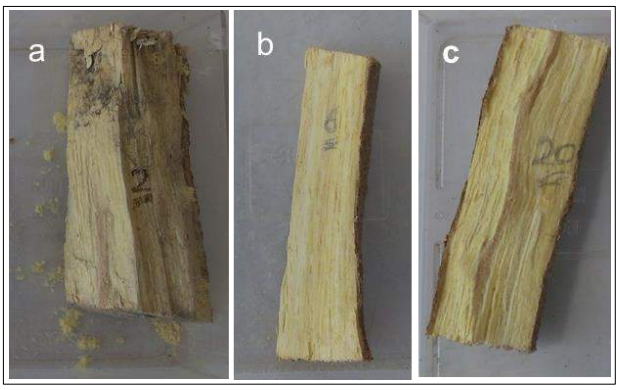
F value 16.66 L.S.D5% 0.14

Each value represents the mean of 3 replicates ±S.E.
[a] Means with the same letters in same column were not significantly different.

Table (5): Weekly mortality percentage of one-week-old *Lyctus africanus* adults irradiated with gamma radiation

Dose (Gy)	% Mortality of adults after treatment			Total
	1st week	2nd week	3rd week	
Control	0.0	0.0	0.0	0.0[a]
50	6.7±1.1	6.7±1.1	13.3±0.7	26.7±0.7
100	26.7±1.1	13.3±1.2	6.7±1.1	46.7±1.2
150	46.7±1.1	20.0±1.2	0.0	66.7±0.7
200	80.0±1.3	0.0	0.0	80.0±1.3
250	100	0.0	0.0	100

F value 40.1 L.S.D 5% 1.78 Each value represents the mean of 3 replicates ±S.E. [a] Means with the same letters in same column were not significantly different.



a. Control. b. Newly hatched larvae irradiated with 100Gy. c. Full grown larvae irradiated with 80Gy.

Fig. (1): Blocks of Poinciana royal wood infested with larvae of *L. africanus*.

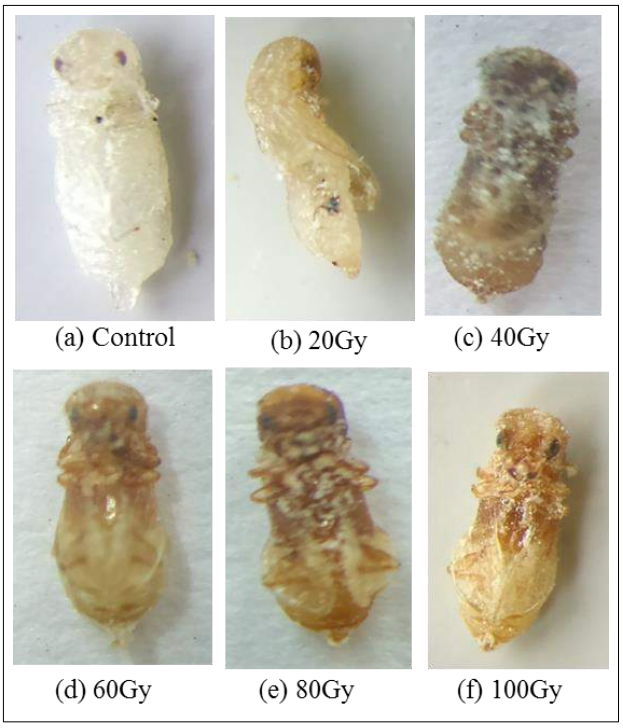


Fig. (2): Photomicrograph of ventral surface of full grown pupae of *L. africanus* unirradiated (control) and irradiated with 20, 40, 60, 80 and 100Gy of gamma radiation, showing some malformation.

adult emergence and vice versa. The mean numbers of *L. africanus* emerged adults from irradiated full grown larvae with 20, 40 and 60Gy were 7.6, 3.3 and 0.6 insects, respectively comparing to 15.3 insects in the control in the first week of inspection. In the second week, the mean number of emerged adult was 3.0 insects in control. While for the full grown larvae irradiated with 20, 40 and 60Gy, the mean number of emerged adults attained 2.3, 0.3 and 0.6 insects, respectively. The mean numbers of *L. africanus* adults were 1.0 and 1.0 insect at the doses of 20 and 40Gy, respectively, compared to 2.6 insects in control in the third week, while no adult emerged at the dose of 60Gy. In other words, the total mean numbers of adults emerged from irradiated full grown larvae of *L. africanus* decreased significantly from 24.3 insects in control to 11.0, 4.6 and 1.3 insects at the treatments of 20, 40 and 60Gy, respectively (Table 2).

There was a significant positive correlation between the doses of gamma radiation and the reduction percentage. No adults emerged at the doses of 80 and 100Gy (Table, 2). Percentage reduction of emerged adults resulted from irradiated larvae with 20, 40, 60, 80 (Fig. 1c) and 100Gy was 54.7, 81.1, 94.6, 100 and 100%, respectively.

Data in table (3) show the loss in weight of infested wood with newly hatched larvae of *L. africanus* after exposure to gamma radiation. As a result of larval mortality by radiation the loss of wood weight was significantly decreased. As well, the loss in wood weight due to larval feeding decreased from 0.59gm in the control to 0.13gm at the highest radiation dose 100Gy. On the other hand, the loss in wood weight decreased from 7.2% in control to 1.7% when the wood was irradiated with 100Gy.

When infected wood with full grown larvae was exposed to different doses of gamma rays, it was noted that the percentage of losses in wood weight affected significantly among different doses (Table 4). The loss of wood weight decreased from 7.2% in control to 3.8, 2.8, 2.0, 0.9 and 1.7% at doses of 20, 40, 60, 80 and 100Gy, respectively.

Effects of gamma radiation on *Lyctus africanus* irradiated pupae

The results showed that no adults emerged from irradiated full grown pupae of *L. africanus* at all doses. The exposure of pupae to different doses of gamma irradiation (20 up to 100Gy) showed malformation effects (Fig. 2a, b, c, d, e, f).

Effects of Gamma Radiation on *Lyctus africanus* Irradiated as Adult

One-week-old adults showed highest tolerance to irradiation than those irradiated as larvae and pupae. Results stated that dose of 250Gy caused 100% mortality in adults of *L. africanus*. Highest percentage of adult mortality occurred in the first week of inspection at all doses. Mortality percentages were 6.7, 26.7, 46.7, 80 and 100% at the doses of 50, 100, 150, 200 and 250Gy, respectively compared to 0% in control. Total mortality percentages of adult weevils after 3 weeks were 26.7, 46.7, 66.7,80 and 100% at correspondent doses of gamma radiation (Table, 5)

Curling and Winandy (2008) reported that dose rate and total dose of gamma radiation differently affect both bending strength and some chemical components in tested wood. According to Kunstadt (1998), insects do not withstand doses between 0.7 and 1.3kGy. Unger *et al.* (2001) mentioned that the doses between 0.25 and 3kGy were adequate for extermination of wood-destroying insects, depending on species and developmental stage. Severiano *et al.* (2010) reported no influence of gamma radiation on some wood physical, thermal and mechanical properties in the radiation dose range between 25 and 100kGy. Despot *et al.* (2012) studied the physical properties of gamma irradiated wood and stated that gamma radiation led to significant color changes in wood and with increasing radiation dose the darkening of the specimens increased (30 up to 150kGy).

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