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Management of cigarette beetle (*Lasioderma serricorne* Fabricius) in turmeric (*Curcuma longa* Linnaeus) by using of gamma radiation

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Abstract
An experiment was conducted to study the management of cigarette beetle by exposing to different doses of gamma radiation of 200 Gy, 400 Gy, 600 Gy, 800 Gy, 1000 Gy and 1200 Gy along with untreated check treatments showed that increase in the dose of gamma radiation resulted in the increase of mortality percentage and decrease in the fecundity and adult emergence. Among all the treatments, the dose of 1200 Gy showed superior performance over other treatments and was adjudged as the best treatment which resulted in complete mortality in short time (8 days) and prevented the subsequent development of the pest.

Keywords: Turmeric, cigarette beetle and nano particles

Introduction
Turmeric is a rhizomatous herbaceous perennial plant belonging to the ginger family (Zingiberaceaae), botanically known as *Curcuma longa* Linnaeus, originated from Tropical south Asia (India) (Ravindran *et al.,* 2007) [31]. It is one of the oldest spices and an important spice bowl of India which had been used since ages. The world production of turmeric stands at around 8, 00,000 tons in which India hold a share of approximately 75 to 80 per cent. India consumes around 80 per cent of its own production (INDIASTAT.COM- 2015) [21]. In India the total area under cultivation is 184.4 thousand hectares with production of 830.40 thousand metric tonnes and productivity of 4.50 MT Ha^{-1} (INDIASTAT.COM- 2015) [21]. Among all the states, Telangana state stands first in area with 43.50 thousand hectares and production of 216.30 thousand metric tonnes while Himachal Pradesh stands first in productivity with 17.90 MT Ha^{-1} (INDIASTAT.COM- 2015) [21]. Various insects have been recorded on dry turmeric, which belong to the order coleoptera, include cigarette beetle (*Lasioderma serricorne* Fab.), drugstore beetle (*Stegobium paniceum* L.), red flour beetle (*Tribolium castaneum* Herbst) lesser grain borer (*Rhyzopertha dominica* Fab.), saw toothed grain beetle (*Oryzaephilus surinamensis* L.) and coffee bean weevil (*Araecerus fasciculatus* DeG.) (Ravindran *et al.,* 2007) [31]. Among all these insects, the cigarette beetle (*Lasioderma serricorne* Fab.) is serious. The damage loss by cigarette beetle in turmeric in terms of quantitative weight loss at three and six months after storage was recorded as 7.15 and 22.75 per cent in turmeric (Vidya and Awaknavar, 1994) [36].

Fumigants and other insecticides are widely used to control stored grain pests but residues and development of resistance in certain species have been of some concern (Champ and Dyte, 1976) [11]. Furthermore, fumigation is being increasingly restricted for environmental reasons. Methyl bromide was phased out and phosphine has less application which makes unsuitable for many disinfestation requirements. As options become more limited, countries can be expected to increasingly turn to irradiation as an alternative treatment (Pszczola, 1997) [30]. Moreover, the residue-free advantages of irradiation disinfestation over chemical fumigation have been demonstrated repeatedly (Tuncbilek, 1995) [35]. The use of ionizing radiation has been recommended not only as a possible alternative but also as a supplement to other control methods (Cornwell 1966, Watters 1968) [12, 37]. Irradiation, unlike chemicals, leaves no residues in treated food. Several works had been done on the use of radiation to control stored product pests (Brower and Tilton, 1983, Hasan, 1999, Azelmat *et al*., 2005 Boshra and Mikhaiel, 2006) [9, 19, 7, 8].

Gamma irradiation treatments have been used for the sterilization of various stored product pests and disinfestation in the quarantine (Hallman, 2000, Fields and White, 2002, Follett and Neven, 2006) [18, 14, 15]. Irradiation is an approved method for the direct control of stored product insects in wheat and flour in many countries and probably would be approved for all grain, grain products and other dry food commodities (Brower and Tilton, 1983). The advantages of irradiation as a pest control measure include the absence of undesirable residues in the foods treated, no resistance development by pest insects (Ahmed, 2001, Lapidot *et al*., 1991) [5, 24].

Gamma chamber

Gamma chamber 5000 was used for giving radiation treatments. It is compact shelf shielded Cobalt^{60} gamma irradiator providing an irradiation volume of approximately 5000cc. The material for irradiation was placed in an irradiation chamber located in vertical drawer inside the lead flask. This drawer can be moved up and down with the help of a system of motorized drive, which enables precise positioning of the irradiation chamber at the center of the irradiation field. Radiation field was provided with service sleeves for grasses, thermocouple, etc. mechanism for rotating / stirring samples during irradiation was also incorporated. The Lead shield provided around the source was adequate to keep the external radiation field well within permissible limits.

The quantity absorbed dose (kGy) can be defined as the amount of energy absorbed per unit mass of the matter at a point of interest.

1 Gy = 100 rads

1 kGy = 1000 Gy

Since the spice is being widely used for consumption, there is a need to test use of biorational approaches for management of *L. serricorne* is need of hour.

In view of serious losses in storing the turmeric from the infestation and a search for the possible biorational, the present investigation was taken up.

Materials and Methods

Management of cigarette beetle by using the gamma radiation was carried out at Quality control lab, EEI premises, Rajendranagar, Hyderabad and at laboratory of Department of entomology, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana During 2014-16.

Experimental setup

Preparation of insect culture:

The parental culture of *L. serricorne* was procured from the local farmers having the infestation on stored cured turmeric rhizomes. For maintaining the culture, about twenty pairs of adult beetles were released into glass jars (20 X 15 cm) containing 500 g of disinfested turmeric powder and the mouth of the jar was covered with muslin cloth and tied with rubber bands. Fifty of such jars were maintained for mass culturing of test insect. The jars were kept undisturbed under laboratory conditions (28 ± 2 °C temperature and 70 per cent relative humidity) till the emergence of F_1 adults. The pest was mass cultured in the laboratory for 4-5 generations and the freshly emerged adults were used in the experimental study. The males and females were identified by careful observation of the external genitalia and the size of the insects. The females are bigger in size than males.

Treatment details of doses of gamma radiation used in the management of *L. serricorne*

S. No.	Treatments	Exposure time (Minutes)
1	200 Gy	6.82 min
2	400 Gy	13.64 min
3	600 Gy	20.45 min
4	800 Gy	27.27 min
5	1000 Gy	34.09 min
6	1200 Gy	40.09 min
7	Untreated check	0

The adults (3+1days) were irradiated at varying doses of exposure periods by a Cobalt^{60} gamma irradiator (Gamma Chamber 5000) having 1.96 KGy hr^{-1} dose rate (Table 1). Each treatment was consisted of 25 adults replicated thrice. The insects were placed in a plastic tube and exposed to gamma radiation at the centre. A control was maintained without any exposure to radiation. Treated and untreated insects were held in the same conditions after the exposure to radiation. The insects after exposing to radiation were placed in the jars containing 100 grams of cured turmeric rhizomes. The data on mortality after irradiation of adults recorded after 24 hours of period of treatment up to 12 days and progeny of F_1 adults emerged from the exposed treatments were taken and data was analyzed statistically by subjecting to analysis of variance using Completely Randomized Design (CRD).

$$\text{Per cent adult mortality} = \frac{\text{Number of adults dead}}{\text{Total number of adults released}} \times 100$$

Results and Discussion

Effect of gamma radiation on adult mortality of *L. serricorne*

The adult mortality of *L. serricorne* exposed to different doses of gamma radiation indicated that low doses of gamma radiation *i.e.,* 200, 400 and 600 Gy did not shown any effect on adult mortality at two days after treatment and even at twelve days after treatment also the mortality reached to 9.33, 34.67 and 58.67 per cent, respectively (Table 2). Higher doses of 800 and 1000 Gy also recorded low mortality (17.33 and 22.67 per cent, respectively), at two days after treatment and it increased to 73.33 and 94.67 per cent, respectively at twelve days after treatment. Among all the doses, 1200 Gy dose was proved to be significantly superior to other treatments and untreated control, where 29.33 per cent adult mortality was observed at one day, 34.67 per cent of adult mortality at two days after treatment and all the adults exposed to 1200 Gy dose of gamma radiation died at eight days after treatment. The overall mean adult mortality (Fig.1) results obtained from different gamma radiation treatments showed superior performance of 1200 Gy over other treatments and was adjudged as the best treatment which resulted in complete mortality in short time.

The results were in agreement with the findings of Titima (2003) [34] who reported that there was complete mortality of *Lasioderma serricorne* when exposed to dose of 1200 Gy. The results were also in agreement with the findings of Tilton *et al*. (1966) [33], Burov (1973) [10], Padwal Desai *et al*. (1987) [27], Abdelbaki (1996) [3], Ignatowicz (2004) [20], Osae *et al*. (2006) [26], Amanda *et al*. (2007) [6], Juliana (2007) [23], Juliana and Marcos (2008) [22],

El-Naggar and Mikhaiel (2011) [13] who reported that the higher dose of gamma radiation was detrimental to cigarette beetle, *L. serricorne* and resulted in increased adult mortality with increase in the dose of gamma radiation in different stored products. Similar findings were also reported by Richard and Patrick (2014) against *S. zeamais* and *C. maculatus* in maize and cow pea, respectively, Saad and Kabbashi (2014) [32] against *T. castaneum* in Composite flour (80 per cent wheat and 20 per cent sorghum) and Ahmadi *et al.* (2013) [4] against T. castaneum and Prabhakumary *et al.* (2011) [29] against T. castaneum in cashew kernels.

Table 2: Effect of gamma radiation on adult mortality of *L. serricorne*

Treatment	Dosage	Per cent adult mortality											
		Days after treatment (DAT)											
		1	2	3	4	5	6	7	8	9	10	11	12
T_1	200 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.67 (7.68)	4.00 (11.53)	6.67 (14.79)	8.00 (16.42)	9.33 (17.70)
T_2	400 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.33 (13.16)	8.00 (16.07)	13.33 (21.36)	16.00 (23.46)	18.67 (25.55)	22.67 (28.40)	29.33 (32.76)	34.67 (36.04)
T_3	600 Gy	0.00 (0.00)	0.00 (0.00)	9.33 (17.70)	16.00 (23.46)	21.33 (27.47)	25.33 (30.19)	30.67 (33.60)	38.67 (38.42)	45.33 (42.30)	49.33 (44.60)	54.67 (47.66)	58.67 (49.97)
T_4	800 Gy	0.00 (0.00)	17.33 (24.56)	20.00 (26.48)	26.67 (31.06)	33.33 (35.24)	38.67 (38.42)	42.67 (40.76)	49.33 (44.60)	57.33 (49.20)	62.67 (52.32)	68.00 (55.55)	73.33 (58.90)
T_5	1000 Gy	0.00 (0.00)	22.67 (28.40)	30.67 (33.60)	37.33 (37.64)	44.00 (41.53)	50.67 (45.36)	58.67 (49.97)	65.33 (53.91)	78.67 (62.48)	86.67 (68.60)	90.67 (72.26)	94.67 (76.80)
T_6	1200 Gy	29.33 (32.76)	34.67 (36.04)	49.33 (44.60)	62.67 (52.32)	74.67 (59.77)	82.67 (65.40)	90.67 (72.26)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)
T_7	0 Gy (Control)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
CD		0.96	1.82	2.75	2.66	2.99	3.53	2.52	5.16	2.01	2.81	2.57	2.90
SE(m)		0.31	0.59	0.90	0.87	0.97	1.15	0.82	1.68	0.65	0.92	0.84	0.94
CV (%)		11.65	8.12	8.91	7.30	6.69	7.16	4.57	7.92	2.83	3.73	3.23	3.49

Figures in parentheses are angular transformed values

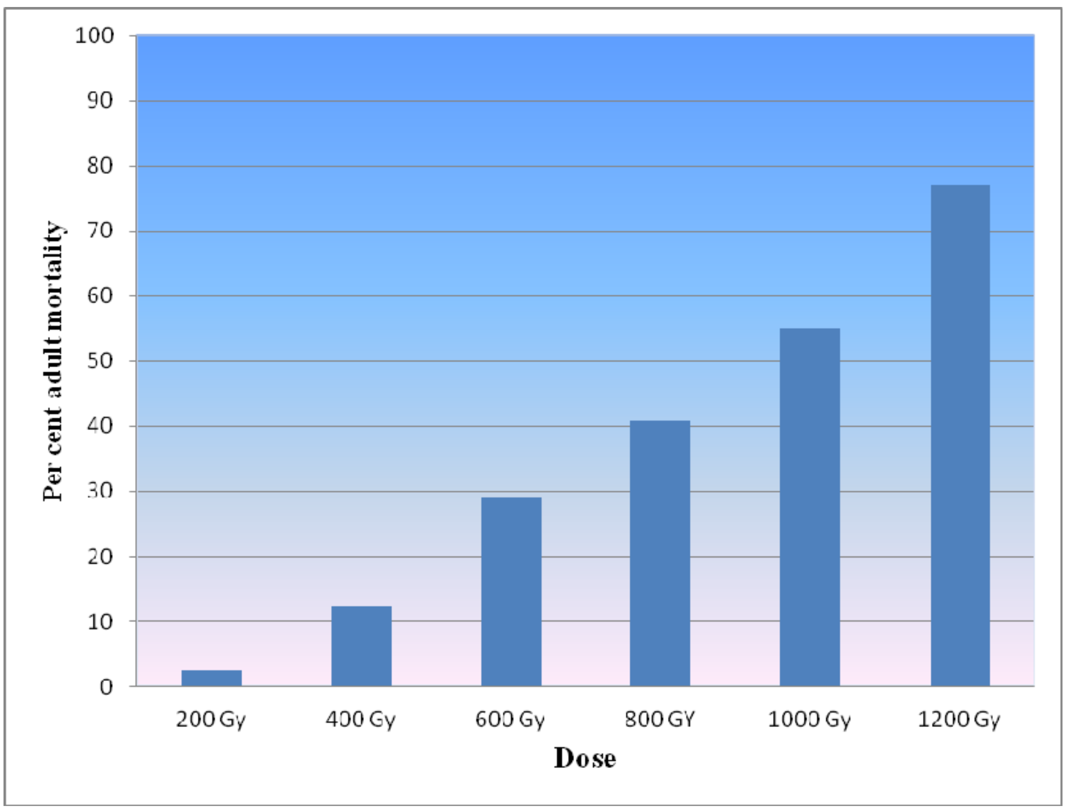

Fig 1: Effect of gamma radiation on mean adult mortality of *L. serricorne* Effect of gamma radiation on fecundity and adult emergence of *L. serricorne*

The fecundity and adult emergence studies indicated the superior performance of 1200 Gy dose treatment over other gamma radiation treatments (Table 3). Since the higher dose of gamma radiation (1200 Gy) resulted in complete mortality of adults at eight days after treatment, the egg laying was low (3.67) and there was no adult emergence. The lower doses of gamma radiation (200, 400 and 600 Gy) resulted in higher oviposition of 66.67, 54.67 and 37.33 eggs, respectively. In the next higher dose of gamma radiation *viz*., 800 and 1000 Gy treatments the fecundity recorded were 24.67 and 10.33, respectively. The number of adults emerged in the lower doses of gamma radiation (200, 400 and 600 Gy) varied from 58.33 to 21.67 showing the least efficacy of 200 Gy dose over the other treatments. The higher doses of gamma radiation *i.e.*, 800 and 1000 Gy recorded the adult emergence of 12.33 and 1.67. In case of 1200 Gy, the few eggs laid by the insect

did not develop into adults, indicating the superior performance of 1200 Gy dose treatment over other treatments. The results were in accordance with the findings of Titima (2003) [34] who reported that dose of 1000 Gy completely prevented the emergence of adults in *L. serricorne*. Juliana and Marcos (2008) [22] reported that there was 100 per cent mortality and failure in the emergence of adults at dose of more than 1.00 kGy for cigarette beetle,
L. serricorne, while Amanda *et al*. (2007) [6] reported that the lethal dose of gamma radiation required for disinfestation of *L. serrricorne* was 1.75 kGy. Padwal-Desai *et al*. (1987) found no emergence of adults of *O. surinamensis* treated with gamma radiation at dose of more than 1000 Gy. Peter *et al*. (2013) [28] reported that there was decrease in the number of adult emergence of *Sitophilus oryzae* with increase in the dose of gamma radiation. Abbas and Nouraddin (2011) [1] reported that the high dose of gamma radiation above 700 Gy have controlled population growth and prevented adult emergence of *Tribolium castaneum.* Boshra and Mikhaiel (2006) [8] indicated that a dose of 1000 Gy killed all date moth, *Ephestia calidella* stages and also prevented the emergence of adults. The increase in the dose of gamma radiation thus resulted in the increase of mortality percentage decrease in the fecundity and adult emergence. The results were in conformity with the findings of Osae *et al*., 2006 [26], Abbas *et al*., 2010 [2], Prabhakumary *et al*. (2011) [29], Mamta *et al*. (2003) [25] and Tuncbilek (1995) [35].

Table 3: Effect of gamma radiation on fecundity and adult emergence of *L. serricorne*

Treatment	Dosage	Fecundity	Number of adults emerged
T_1	200 Gy	66.67 (8.22)	58.33 (7.70)
T_2	400 Gy	54.67 (7.46)	43.67 (6.68)
T_3	600 Gy	37.33 (6.19)	21.67 (4.75)
T_4	800 Gy	24.67 (5.06)	12.33 (3.64)
T_5	1000 Gy	10.33 (3.36)	1.67 (1.57)
T_6	1200 Gy	3.67 (2.13)	0.00 (1.00)
T_7	0 Gy (Control)	93.33 (9.71)	90.00 (9.53)
C.D. (P=0.05)		0.33	0.40
SE(m)		0.10	0.13

*Figures in parentheses are square root transformed values

Irradiation, whether by isotopes or machine sources (e-beam or X-ray), has the same mode of action: the gamma rays, X-rays, or electrons knock electrons out of their orbits, creating ions and radicals. The free electrons collide with further electrons resulting in an electron shower. The ions and radicals cause further damage to large organic molecules such as DNA stopping development of irradiated organisms. Indeed, the secondary damage caused by ions and radicals produced by the electron shower may cause more damage to organic molecules than the primary radiation itself. In organisms, radiation most easily affects sites of ongoing cell division, which in the adult insect include the gonads and midgut. At minimal doses they stop the functions of these organs insects will not reproduce and will cease feeding because the midgut cannot process food (Hallman, 2013) [17]. Ghogumu (1991) [16] and Prabhakumary *et al*. (2011) [29] reported that the irradiation will affect the reproductive ability of adult females and progeny by causing sterility and inhibition of sexual ability.

Conclusions

Gamma radiation at dose of 1200 Gy was adjudged as the best treatment which resulted in complete mortality in short time (8 days) and prevented the subsequent development of the *L. serricorne*.

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