Agriculture Association of Textile Chemical and Critical Reviews Journal (2022) 01-18

AATCC Review

25 July 2022: Received
27 August 2022: Revised
30 September 2022: Accepted
19 October 2022: Available Online

http://aatcc.peerjournals.net/

Research Article

Open Access

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

K Ravi Kumar[1], C Narendra Reddy[1], K Vijaya Lakshmi[1], K Rameash[2], K Keshavulu[3] and B Rajeswari[4]

[1]Department of Entomology, College of Agriculture, Rajendranagar, Telangana, India; Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India
[2]NBPGR Regional Research Station, Rajendranagar, Hyderabad, Telangana, India
[3]TSSOCA Hyderabad, Telangana, India
[4]Department of Plant Pathology, College of Agriculture, Rajendranagar, Telangana, India

Abstract

An experiment was conducted to study the management of cigarette beetle by exposing the adult cigarette beetles to different power levels of microwave radiation at 100, 200, 300, 400, 500 watts and different exposure periods of 30, 60 and 120 seconds indicated that the power levels as well as exposure periods had a significant influence on adult mortality and increasing the exposure period from 30 seconds to 120 seconds and power levels from 100 to 500 watts drastically reduced the time required to cause the mortality of adults. The data revealed that exposure of L. serricorne adults to 500 and 400 power levels for 120 seconds exposure period was the best treatment which resulted in complete mortality of adults at one and four days after treatment respectively, also affected the fecundity and adult emergence of the cigarette beetle.

Keywords: *Turmeric, Cigarette beetle, Lasioderma, Exposure period, Power level, Watts and Microwave radiation.*

Introduction

Turmeric is a rhizomatous herbaceous perennial plant belonging to the ginger family (Zingiberaceaae), botanically known as *Curcuma longa* Linnaeus and originated from Tropical south Asia (India). It is one of the oldest spices and an important spice bowl of India which had been used for ages. The world production of turmeric stands at around 8, 00,000 tons of which India holds a share of approximately 75 to 80 per cent. India consumes around 80 per cent of its own production. In India the total area under cultivation is 184.4 thousand hectares with a production of 830.40 thousand metric tonnes and productivity of 4.50 MT Ha^{-1}. Among all the states, Telangana state stands first in the 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} [12]. Various insects have been recorded on dry turmeric, which belongs to the order coleoptera, including 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.). 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 2004).

**Corresponding Author: K Ravi Kumar*
E-mail Address: katrojuravikumar@gmail.com
DOI:https://doi.org/10.58321/AATCCReview.2022.10.02.19

Control of stored product pests is one of the major tasks because the damage inflicted on foodstuff is irreversible. Also with a progressive increase in the number of food grains and the necessity for longer storage periods, these losses will escalate unless disinfestation measures are improved. The efficient control and removal of stored grain pests from food commodities have long been the goal of entomologists throughout the world. Various methods of insect control have been practiced to save the grain. Conventional chemicals, grain protectants, fumigants are extensively used around the world to control insect pests in stored commodities because of low cost, fast processing, and easy application. Greater regulation and restriction of methyl bromide use likely increased the cost of the fumigant. Phosphine resistance in cigarette beetle, *L.serricorne* was studied in tobacco and reported integrated alternative management strategies have to be followed for control of the pest [20]. The concern about the health hazards of chemical pesticides and their resulting environmental pollution, there is interest in developing alternative, nonchemical process protocol to control insect pests while retaining acceptable product quality. These include microwave (MW) heating. Currently, the use of chemical fumigation remains widespread and the efficient use of microwave methods for disinfestation was still in the research stage. Microwaves are electromagnetic waves with frequencies ranging from about 300 MHz to 300 GHz and corresponding wavelengths from 1 to 0.001m [5]. The frequency used for microwaves is 2450 MHz or 915 MHz. Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting polar molecules of a material. Many molecules in food (such as water and fat) are electric dipoles, meaning that they have a positive charge at one end and a negative charge at the other and therefore they rotate as they try to align themselves with the alternating electric field induced by the microwave beam. The rapid movement of the bipolar molecules creates friction and results in heat dissipation in the material exposed to microwave radiation. The use of microwaves for disinfestation is based on the dielectric heating effect produced in the grain, which is a relatively poor conductor of electricity. An attractive feature of insect control using the microwave energy is that the insects are heated at a faster rate than the product they infest because of the high moisture content of insects. So, it is possible to heat the insects to a lethal temperature because of their high moisture content while leaving the drier foodstuff unaffected or slightly warm [28]. There has been a lot of research on microwave disinfestation of cereals especially wheat [26]; [27]; [3]; [23]; [22]; [9]; [29]; [30] and of some other food materials such as nuts [33] corn [31] and pulses [24], [18]. The use of microwave energy to control insects was initiated by [34]. Exposure to microwave energy could cause physical injuries and reduced reproduction rates in surviving insects [16]. The feasibility of microwave disinfestation of insect pests was explored by [2] for woodworms and by [8] for wheat, maize, and flour weevils [11].

Materials and Methods

The effect of microwave radiation on the cigarette beetle was carried out at NBPGR Regional Research Station, Rajendranagar, Hyderabad. Microwaves are electromagnetic waves with frequencies ranging from about 300 MHz to 300 GHz and corresponding wavelengths from 1 to 0.001m [5]. The use of microwaves for disinfestation is based on the dielectric heating effect produced in grain, which is a relatively poor conductor of electricity. The basic principle in controlling the insect using microwave energy is that the insects are heated at a faster rate than the product they infest because of the high moisture content of insects. Exposure to microwave energy could cause physical injuries and reduced reproduction rates in surviving insects (Nelson 1996).

Microwave oven

An adjustable microwave oven (BPL, Sanyo) with a power output range of 1000 W and frequency of 2,450 MHz was used for the experiment.

Design of experiment

To commence microwave radiation, prior to the treatment 100 grams of cured turmeric rhizomes of the variety "Duggirala" were taken to which 20 adults of cigarette beetles were released where after, 10 days they were kept in the petri dish and placed in a kitchen type, 2450 MHz microwaves oven with a capacity of producing 1000 W microwaves power. For microwave irradiation, five power outputs of the generator were set at 100, 200, 300, 400 and 500 W with exposure periods of 30, 60 and 120 seconds. The control was also maintained without exposure to microwave radiation. After the termination of treatment, the samples along with their respective control groups were maintained at room temperature. Each treatment was replicated thrice.

Insect Mortality

The data on mortality of live and adult insects after irradiation was recorded after 24 hours of period of treatment up to seven days and progeny of F_1 adults that emerged from the exposed treatments was recorded and analyzed statistically. The data were subjected to square root and angular transformation values wherever necessary and analyzed by subject to the analysis of variance using Completely Randomized Design (CRD) and Factorial Completely Randomized Design (FCRD).

The mortality was observed daily and per cent adult mortality was calculated by using the following formula.

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

Results and Discussion

The results obtained from the studies on adult mortality of *L. serricorne* exposed to different power levels of microwave radiation at 100, 200, 300, 400, 500 w and different exposure periods of 30, 60 and 120 seconds are presented in tables 1 to 3.

Adult mortality of *L. serricorne* exposed to different power levels of microwave radiation at 30 seconds of exposure period

The adult mortality of *L. serricorne* exposed to different power levels of microwave radiation after 30 seconds of exposure period indicated that low power levels of microwave radiation *i.e.,* 100 w caused 8.33 per cent mortality of adults at one day after treatment which increased to 33.33 per cent mortality by the seventh day after treatment. The next microwave treatments 200, 300 and 400 w recorded 21.67, 43.33 and 56.67 per cent of adult mortality, respectively at one day after treatment, increased to 53.33, 76.67, 88.33 per cent, respectively at seven days after treatment(Table 1).The mean per cent adult mortality of *L. serricorne* exposed to 100, 200, 300, 400 and 500 w power levels at seven days after treatment was 21.67, 37.62, 59.04, 72.61 and 92.85, respectively. Among all the treatments, the highest mean per cent adult mortality was recorded in 500 w microwave radiation exposed for 30 seconds and this treatment was significantly different from other treatments.

Adult mortality of *L. serricorne* exposed to different power levels of microwave radiation at 60 seconds of exposure period

The results on the exposure of *L. serricorne* adults to different power levels of microwave radiation up to 60 seconds (Table 2) indicated that the low power levels of 100 and 200 w of microwave radiation recorded less than 50 per cent mortality with 26.67 and 38.33, respectively at one day after treatment which increased to 58.33 and 71.67 per cent, respectively at seven days after treatment. The treatment with 400 and 500 w of microwave radiation recorded 71.67 and 93.33 per cent adult mortality, respectively at one day after treatment which increased to cent per cent adult mortality on seventh and second day after treatment, respectively. The highest mean per cent adult mortality at seven days after treatment was recorded in 500 w (99.04) followed by 400 w (86.67), 300 w (75.95), 200 w (55.95) and 100 w (42.14) microwave radiation subjected for 60 seconds and these treatments were significantly different from each other.

Adult mortality of *L. serricorne* exposed to different power levels of microwave radiation at 120 seconds of exposure period

The *L. serricorne* adults subjected to longer exposure periods (Table 3) of 120 seconds showed more than 50 per cent mortality of adults even at a low power level of 200 w (53.33) at one day after treatment and it was further increased to 88.33 per cent at the seventh day after treatment, while the 100 w was least effective and recorded 41.67 per cent adult mortality at one day after treatment which further increased to 75.00 per cent at the seventh day after treatment. Among the mean per cent mortalities of the two treatments *i.e.*, 200 w (71.42) and 100 w (60.71), the treatment of 200 w showed superior performance than 100 w power level which was significantly different from each other. The next higher power levels of 300 and 400 w recorded 76.67 and 86.67 per cent mortality by the first day and obtained complete hundred per cent adult mortality by the sixth and fourth day after treatment, respectively. Hundred per cent of adult mortality was recorded in the case of 500 w power level at one day after treatment and found to be superior in performance than the remaining treatments. The highest mean per cent adult mortality was recorded in 500 w power level with cent per cent followed by 400 w (96.42), 300 w (90.71), 200 w (71.42) and 100 w (60.71), these treatments were significantly different

Table 1 Effect of microwave radiation on adult mortality of L. serricorne at 30 seconds of exposure period

Power level (W)	Per cent adult mortality							
	Days after treatment (DAT)							
	1	2	3	4	5	6	7	Mean
100	8.33 (16.59)	11.67 (19.87)	18.33 (25.29)	23.33 (28.84)	25.00 (29.98)	31.67 (34.21)	33.33 (35.23)	21.67 (27.72)
200	21.67 (27.69)	26.67 (31.05)	30.00 (33.19)	36.67 (37.24)	46.67 (43.07)	48.33 (44.02)	53.33 (46.89)	37.62 (37.81)
300	43.33 (41.14)	51.67 (45.93)	56.67 (48.81)	58.33 (49.78)	61.67 (51.73)	65.00 (53.70)	76.67 (61.12)	59.04 (50.19)
400	56.67 (48.81)	63.33 (52.72)	66.67 (54.72)	73.33 (58.90)	76.67 (61.12)	83.33 (65.92)	88.33 (70.08)	72.61 (58.42)
500	81.67 (64.66)	86.67 (68.63)	91.67 (73.37)	93.33 (75.21)	96.67 (81.36)	100.00 (90.00)	100.00 (90.00)	92.85 (74.48)
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)
CD (P=0.05)	3.62	3.42	3.34	3.53	5.94	2.39	2.94	0.93
SE(m)	1.16	1.09	1.07	1.13	1.90	0.76	0.94	0.29
CV (%)	6.08	5.23	4.74	4.72	7.41	2.77	3.24	1.25

Figures in parentheses are angular transformed values

Table 2 Effect of microwave radiation on adult mortality of L. serricorne at 60 seconds of exposure period

Power level (W)	Per cent adult mortality							
	Days after treatment (DAT)							
	1	2	3	4	5	6	7	Mean
100	26.67 (31.05)	33.33 (35.23)	36.67 (37.24)	41.67 (40.18)	46.67 (43.07)	51.67 (45.93)	58.33 (49.78)	42.14 (40.46)
200	38.33 (38.22)	45.00 (42.11)	51.67 (45.93)	53.33 (46.89)	63.33 (52.72)	68.33 (55.74)	71.67 (57.83)	55.95 (48..39)
300	58.33 (49.78)	66.67 (54.72)	70.00 (56.76)	78.33 (62.26)	81.67 (64.66)	86.67 (68.63)	90.00 (71.53)	75.95 (60.61)
400	71.67 (57.83)	73.33 (58.90)	81.67 (64.66)	85.00 (67.18)	96.67 (81.36)	98.33 (85.68)	100.00 (90.00)	86.67 (68.56)
500	93.33 (75.21)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	99.04 (84.44)
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)
CD (P=0.05)	3.50	2.28	2.37	2.26	5.98	6.05	1.83	1.25
SE(m)	1.12	0.73	0.75	0.72	1.92	1.94	0.58	0.40
CV (%)	4.63	2.71	2.68	2.45	6.01	5.84	1.70	1.38

Figures in parentheses are angular transformed values

from each other.

The results of overall mean adult mortality studies of *L. serricorne* with different power levels of microwave radiation (Table 4) revealed that the lowest per cent adult mortality was obtained with 100 w power level (41.50) which was significantly different from 200 w (55.00). Exposure of adults to the higher power levels *viz.,* 300 and 400 w showed significant variation by recording mortality of 75.23 per cent and 85.21 per cent, respectively. Among all the treatments, significantly the highest mean per cent adult mortality of 97.30 was obtained with 500 w power level. There was no adult mortality in the untreated control.

The effect of various exposure periods at different power levels of microwave radiation (Table 4) also showed significant variation in adult mortality. Exposure of adults to the lowest period of 30 seconds recorded the lowest per cent adult mortality of 47.30 followed by 59.96 per cent mortality with 60 seconds exposure period. An increase in exposure periods resulted in increased mortality rates. Significantly the highest mean adult mortality of 69.88 per cent was recorded with the longest exposure periods of 120 seconds in all the power levels.

The interaction effect of power levels and exposure periods also showed significant variations. Among all the interactions, exposure of adults insects to 500 w power levels for 60 and 120 seconds resulted in almost complete mortality (100 per cent) while exposure to the low power level (100, 200, 300 and 400 w) and low exposure period (30 seconds) resulted in significantly the lowest adult mortality (21.67, 37.62, 59.04 and 72.61 per cent, respectively).

The overall findings obtained from adult mortality studies of *L. serricorne* when exposed to different power levels and exposure periods of microwave radiation (Tables 1 to 3) indicated that the power levels as well as exposure periods had significant influence on adult mortality and increased the exposure period from 30 seconds to 120 seconds and power levels from 100 to 500 w drastically reduced the time required to cause the mortality of adults. Hence it can be inferred from the data that exposure of *L. serricorne* adults to 500 and 400 power levels for 120 seconds exposure period were the best treatments which resulted in complete mortality of adults at one and four days after treatment, respectively. The results were in agreement with the findings of [1] who reported that complete mortality of *T. confusum* adults and 98.8 per cent mortality of *Callosoburchus maculatus* adults was recorded when exposed to 400 w and concluded that an increase in the power levels and exposure periods will increase in mortality. Similar findings were also reported by, [15] who reported that complete mortality of *Callosobruchus maculatus* was achieved at high power levels for 60 and 120 seconds exposure period. [21] reported that complete mortality of *C. chinensis* was observed at 120 seconds exposed to 560 watts of power. [29] reported that the complete mortality of *T. castaneum* was achieved at 500 watts. Thus, the increase in exposure time and power level has resulted in increased mortality of *L. serricorne* adults. Similar findings were also reported against different stored products pests by [6]; [14]; [19]; [17].

There are three temperature zones for all insects: optimum, the zone at which the highest rate of development can be achieved; suboptimum, a zone below or above optimum during which insects can complete their life cycle; and thirdly lethal zone, above or below suboptimum zones when insects get killed over a period of time [13]. Insects under microwave irradiation are prone to some types of stress such a controlled atmosphere and cold [33]. The warehouse environment is usually one that is enclosed, allowing for the manipulation of the temperature. Thus, the use of temperature to restrict insect populations was an excellent tool for the stored product industry. Exposure to temperatures only 5°C above the optimum can slow or stop insect activity development and depending on the species, was capable of causing death [7]. Exposure to a temperature above 55°C for short periods of time may cause 100 per cent mortality [35] while [25] reported that the hazardous impact of microwave radiation on insects may be due to a high oscillation frequency of water molecules in the body of insects.

The present findings confirmed that exposure of *L. serricorne* adults to 400 and 500 w for 120 seconds was considered the best treatment for control of adult cigarette beetle and these treatments can be recommended for effective management of the stored grain pests as treatment of food grains which was in compliance with the international environmental rules and with the requirements of the Montreal Protocol [33].

Effect of microwave radiation on fecundity and adult emergence of *L. serricorne*

The results on the effect of microwave radiation on fecundity and adult emergence of *L. serricorne* are presented in table 5 and fig. 1. The data revealed that the treatments with higher microwave radiation of 500 w recorded the lowest fecundity of 2.67 at 30 seconds exposure period and did not record any fecundity at 60 and 120 seconds exposure whereas in control the fecundity ranged from 86.67 to 91.33. Among all the power levels the lowest power level of 100 w was the least effective and recorded 36.67, 28.67 and 13.33 eggs at 30, 60 and 120 seconds of the exposure period, respectively. Whereas 200 and 300 w power level recorded 23.33, 16.67 (30 seconds),

Table 3 Effect of microwave radiation on adult mortality of L. serricorne after 120 seconds of exposure period

Power level (W)	Per cent adult mortality							
	Days after treatment (DAT)							
	1	2	3	4	5	6	7	Mean
100	41.67 (40.18)	50.00 (44.98)	56.67 (48.81)	61.67 (51.73)	66.67 (54.72)	73.33 (58.90)	75.00 (59.97)	60.71 (51.16)
200	53.33 (46.89)	61.67 (51.73)	68.33 (55.74)	70.00 (56.76)	76.67 (61.12)	81.67 (64.66)	88.33 (70.08)	71.42 (57.66)
300	76.67 (61.12)	83.33 (65.92)	86.67 (68.63)	91.67 (73.37)	96.67 (81.36)	100.00 (90.00)	100.00 (90.00)	90.71 (72.25)
400	86.67 (68.63)	93.33 (75.21)	95.00 (77.04)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	96.42 (79.11)
500	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
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)
CD (P=0.05)	2.91	3.09	2.56	2.65	5.82	2.10	1.85	1.28
SE(m)	0.93	0.99	0.82	0.85	1.87	0.67	0.59	0.41
CV (%)	3.17	3.15	2.51	2.47	5.15	1.78	0.83	1.22

Figures in parentheses are angular transformed values

Table 4 Effect of power levels of microwave radiation and exposure periods on mean adult mortality of L. serricorne

Power level (W)	Per cent adult mortality			
	Days after treatment (DAT)			
	30 seconds	60 seconds	120 seconds	Mean
100	21.67 (27.72)	42.14 (40.46)	60.71 (51.16)	41.50 (39.80)
200	37.62 (37.81)	55.95 (48..39)	71.42 (57.66)	55.00 (47.97)
300	59.04 (50.19)	75.95 (60.61)	90.71 (72.25)	75.23 (61.04)
400	72.61 (58.42)	86.67 (68.56)	96.42 (79.11)	85.21 (68.72)
500	92.85 (74.48)	99.04 (84.44)	100 (90.00)	97.30 (81.64)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Mean	47.30 (42.13)	59.96 (51.11)	69.88 (58.38)	
	CD (P=0.05)		SE(m)	
Power level (F_1)	0.43		0.15	
Exposure period (F_2)	0.62		0.21	
Interaction (F_1 X F_2)	1.09		0.37	
CV (%)	3.23			

Figures in parentheses are angular transformed values

Table 5 Effect of microwave radiation on fecundity and adult emergence of L. serricorne

Power level (W)	Fecundity			Number of adults emerged		
	30 seconds	60 seconds	120 seconds	30 seconds	60 seconds	120 seconds
100	36.67 (6.13)	28.67 (5.44)	13.33 (3.78)	30.33 (5.59)	19.33 (4.50)	7.67 (2.93)
200	23.33 (4.93)	18.33 (4.39)	8.67 (3.10)	14.67 (3.95)	10.67 (3.41)	3.67 (2.13)
300	16.67 (4.20)	11.67 (3.55)	5.67 (2.57)	9.67 (3.26)	6.33 (2.69)	1.33 (1.52)
400	12.67 (3.69)	4.33 (2.29)	0.00 (1.00)	5.33 (2.50)	0.67 (1.27)	0.00 (1.00)
500	2.67 (1.88)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Control	86.67 (9.36)	90.00 (9.53)	91.33 (9.60)	81.33 (9.07)	87.33 (9.39)	89.67 (9.52)
CD(P=0.05)	0.41	0.33	0.29	0.35	0.26	0.31
SEm ±	0.14	0.11	0.09	0.11	0.08	0.10
CV (%)	3.51	4.21	4.60	4.38	3.97	5.68

*Figures in parentheses are square root transformed values

18.3, 11.67 (60 seconds) and 8.67, 5.67 (120 seconds) eggs, respectively.

The fecundity recorded in the power level 400 w was recorded 12.67 and 4.33 eggs at 30 and 60 seconds respectively, but there was no fecundity observed at 120 seconds. The increase in the power level and exposure period has resulted in decreasing in fecundity. The results were in agreement with the findings of [1] who reported that the number of eggs laid by *Tribolium confusum* and *Callosobruchus maculatus* was decreased at 400 watts and above with an increase in microwave exposure periods. Similar findings were reported by [29] who did not observe any fecundity of *T. castaneum* at 500 watts.

The data on fecundity studies revealed that the fecundity of adults was totally arrested when they were exposed to high power levels (400 and 500 w) depending on exposure periods indicating the susceptibility of *L. serricorne* adults to high power levels of microwave radiation. The adults exposed to low power levels of microwave though survived, showed progressive decrease in the fecundity of adults than the untreated control. [4] reported that increasing exposure periods to microwave found a negative effect on fecundity of the insect. The high power level of microwave radiation not only killed the insects but also affected the reproduction of the survivors [10]. Microwave irradiation has deleterious effects on insects such as a reduction of reproductive rate, in the surviving insects [16].

The adult emergence studies of cigarette beetle (Table 5 and Fig. 2) indicated that the microwave power level of 500 w completely checked the fecundity and adult emergence, while 100 and 200 w power levels were not effective in preventing the fecundity and subsequent multiplication of pests. The microwave radiation of 400 w power level though recorded 5.33 of adult emergence at 30 seconds, but decreased to 0.67 at 60 seconds exposure period and no fecundity and adult emergence was observed at 120 seconds exposure period. The highest adult emergence of 81.33, 87.33 and 89.67 was recorded from untreated control at 30, 60 and 120 seconds exposure periods, respectively. From the results it was evident that microwave radiation of 500 w and 400 w at 120 seconds exposure period were detrimental and they affected the fecundity as well as adult emergence of the test insect. The results were in agreement with findings of the [4] reported that in *Delia radicum,* higher power levels and exposure periods caused a significant reduction in progeny production and adverse effects on the multiplication potential of the survivors. [1] reported that there was a decrease in adult emergence of *Tribolium confusum* and *Callosobruchus maculatus* at 400 w power level and above with an increase in exposure periods.

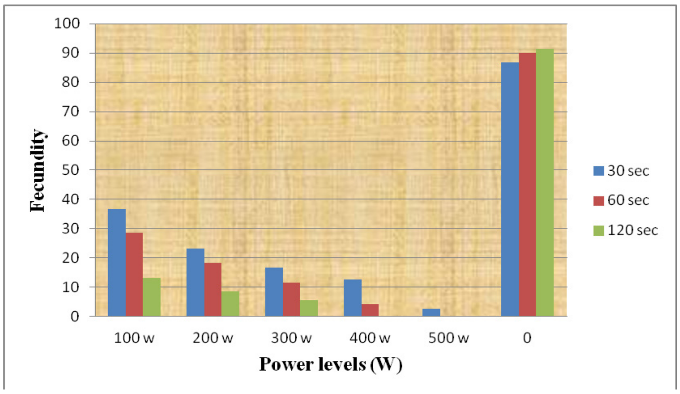

Fig.1. Effect of microwave radiation on fecundity of L. serricorne

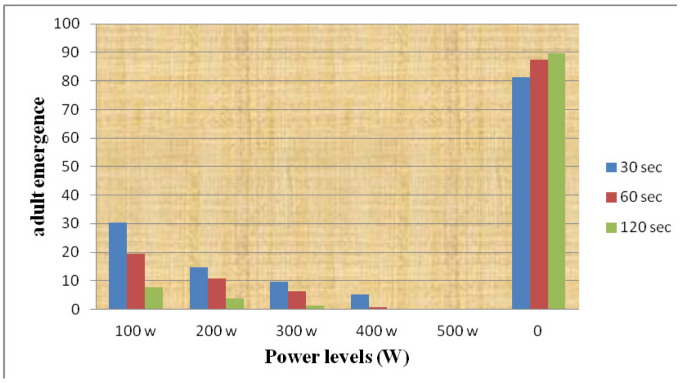

Fig.2. Effect of microwave radiation on adult emergence of L. serricorne

Conclusions

Exposing the adult cigarette beetles to different power levels and exposure periods of microwave radiation, indicated that the power levels as well as exposure periods had **a** significant influence on adult mortality and increasing the exposure period from 30 seconds to 120 seconds and power levels from 100 to 500 watts drastically reduced the time required to cause the mortality of adults. The results inferred that exposure of *L. serricorne* adults to 500 and 400 power levels for 120 seconds exposure period were the best treatments which resulted in complete mortality of adults at one and four days after treatment, respectively and also affected the fecundity and adult emergence of the cigarette beetle.

Acknowledgement

I sincerely thank the Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad, NBPGR Regional Research Station, Rajendranagar, Hyderabad for their constant help in my research work. I felt elated to express my bountiful thanks to those who directly or indirectly helped me in the successful completion of the work The authors are incredibly thankful to the editor and assistant editor for finding interest in the present study. Furthermore, we also thank the anonymous reviewers for their constructive ideas to strengthen the current research work are appreciated as well.

Conflict of interest

The authors declare that they have no conflict of interest

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Funding

The author (s) received financial support from the institutional research grant of Professor Jayashankar Telangana state agricultural University and the Government of Telangana for financial help and for providing research facilities which can't be forgettable.

References

[1.] Ahmady A, Mousa AAM, Ahmed AZ. 2016. Effect of microwave radiation on *Tribolium confusum* Jaquelin du Val (Coleoptera: Tenebrionidae) and *Callosobruchus maculate* (F.) (Coleoptera: Bruchidae). Journal of Entomology and Zoology Studies .4 (4): 12571263.

[2.] Andreuccetti D, Bini M, Ignesti A, Gambetta A, Olmi R. 1994. Microwave destruction of woodworms. Journal of Microwave Power and Electromagnetic Energy. 29 (3): 153-160.

[3.] Bedi SS, Singh M. 1992. Microwaves for control of stored grain insects. National Academy of Science Letter. 15 (6): 195-197.

[4.] Biron D, Vincent C, Giroux M, Maire A. 1996. Lethal effects of microwave exposures on eggs and pupae of the cabbage maggot and cabbage plants. Journal of Microwave Power and Electromagnetic Energy. 31 (2): 228- 237.

[5.] Decareau RV. 1985. Microwaves in the Food Processing Industry. Academic Press, Natick, Mass, USA.

[6.] Dilek pander, Esra guven. 2014. Effect of microwave radiation on stored product pest *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) larvae. Turkish

Journal of Entomology. 38 (2): 135-147.

[7.] Field PG. 1992. The control of stored product insects and mites with extreme Temperatures. Journal of Stored Products Research. 28 (3): 89-118.

[8.] Halverson SL, Burkholder WE, Bigelow TS, Norsheim EV, Misenheimer ME. 1996. High power microwave radiation as an alternative insect control method for stored products. Journal of Economic Entomology. 89 (6): 1638-1648.

[9.] Halverson WR, Bigelow TS, Halverson SL. 2003. Design of high power microwave applicator for the control of insects in stored products. Proceedings of the Annual International Meeting. 27–30.

[10.] Hamid MAK, Kashyap CS, Cauwenberghe RV. 1968. Control of grain insects by microwave power. Journal of Microwave Power. 3 (3): 126-135.

[11.] Ikediala JN, Tang J, Neven LG, Drake SR. 1999. Quarantine treatment of cherries using 915 MHz microwaves: temperature mapping, codling moth mortality and fruit quality. Postharvest Biology and Technology. 16 (2): 127-137.

[12.] Indiastat. 2015. www.Indiastat.com.

[13.] Ipsita Das, Girish Kumar, Narendra GS. 2013. Microwave heating as an alternative quarantine method for disinfestation of stored food grains. International Journal of Food Science. 5 (1): 1-13.

[14.] Manickavasagan A, Alahakoon PMK, Al-Busaidi TK, Al-Adawi S, Al-Wahaibi AK, Al-Raeesi AA, Al-Yahyai R, Jayas, DS. 2013. Disinfestation of stored dates using microwave energy. Journal of Stored Products Research. 55 (2): 1-5.

[15.] Mohapatra D. Saroj G, Abhijit K. 2014. Effect of microwave aided disinfestation of *allosobruchus maculatus* on green gram quality. International Journal of Agriculture and Food Science Technology. 5 (2): 55-62.

[16.] Nelson SO. 1996. Review and assessment of radio frequency and microwave energy for stored grain insect control. Transactions of the American Society of Agricultural Engineers. 39 (4): 1475-1484.

[17.] Orouj V, Ali AP, Safaralizadeh MH. 2011. The impact of microwaves irradiation and temperature manipulation for the control of stored products insects. African Journal of Biotechnology. 10 (61): 13256-13262.

[18.] Pande R, Mishra HN, Singh MM. 2012. Microwave drying for safe storage and improved nutritional quality of green gram seed (*Vigna radiata*). Journal of Agricultural and Food Chemistry. 60 (3): 3809–3816.

[19.] Purohit P, Jayas DS, Yadav BK, Chelladurai V, Fields PG, White NDG. 2013.Microwaves to control *Callosobruchus maculatus* in stored mung bean (*Vigna radiata*).Journal of Stored Products Research. 53 (1): 19-22.

[20.] Rajendran S, Narasimhan KS.1994. Phosphine resistance in the cigarette beetle *Lasioderma serricorne* (Coleoptera: Anobiidae) and overcoming control failures during fumigation of stored tobacco. International Journal of Pest Management. 40(2): 207-210.

[21.] Ranjeet S, Singh KK, Kotwaliwale N. 2012. Study on disinfestation of pulses using microwave technique. Journal of Food Science and Technology. 49 (4): 505–509.

[22.] Sanchez Hernandez D, Balbastre JV, Osca JM. 2002. Microwave energy as a viable alternative to methyl bromide and other pesticides for rice disinfection of industrial processes. Proceedings of International Conference on Alternatives to Methyl Bromide.159-162.

[23.] Shayesteh N, Barthakur NN. 1996. Mortality and behaviour of two stored product insect species during microwave irradiation. Journal of Stored Products Research. 32 (3): 239246.

[24.] Singh R, Singh KK, Kotwaliwale N. 2012. Study on disinfestations of pulses using microwave technique. Journal of Food Science and Technology. 49 (4): 505-509.

[25.] Somayyeh G, Ali AP, Safaralizadeh MH, Mustafa M. 2010. Effect of microwave radiation and cold storage on *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae)and *Sitophilus oryzae* l. (Coleoptera: Curculionidae). Journal of plant protection research. 50 (2): 140-145.

[26.] Tilton EW, Vardell HH. 1982. Combination of microwaves and partial vacuum for control of four stored-product insects in stored grain. Journal of the Georgia Entomological Society. 17(1): 106-112.

[27.] Tilton EW, Brower JH. 1987. Ionizing radiation for insect control in grain and grain products. Cereal Foods World. 32 (4): 330–335.

[28.] Vadivambal R, Jayas DS, White NDG. 2006. Disinfestation of life stages of *Tribolium castaneum* in wheat using microwave energy. Proceedings of the Annual conference, Edmonton, Alberta. 06-120.

[29.] Vadivambal R, Jayas DS, White NDG. 2007. Wheat disinfestation using microwave energy. Journal of Stored Products Research. 43 (5): 508–514.

[30.] Vadivambal R. 2009. Disinfestation of the stored grain insects using microwave energy. *Ph.D. thesis*. University of Manitoba,Winnipeg, Canada.

[31.] Vadivambal R, Deji OF, Jayas DS, White NDG. 2010. Disinfestation of stored corn using microwave energy. Agriculture and Biology Journal. 1 (3): 18-26.

[32.] Vidya H, Awaknavar JS. 2004. Host suitability of different spices to cigarette beetle, *Lasioderma serricorne* Fab. (Anobiidae: Coleoptera). Insect Environment. 10 (4): 176177.

[33.] Wang S, Tang J. 2001. Radio frequency and microwave alternative treatments for insect control in nuts: A review. International Agricultural Engineering Journal. 10 (3): 105120.

[34.] Webber HH, Wangner RP, Pearson AG. 1946. High frequency electric fields as lethal agents for insects. Journal of Economic Entomology. 39 (2): 481-498, 1946.

[35.] Zhao S, Qiu CH, Xiong SH, Cheng X. 2007. A thermal lethal model of rice weevils subjected to microwave irradiation. Journal of Stored Products Research. 43 (5): 430434.

