Int.J.Curr.Microbiol.App.Sci (2017) *6*(6): 1538-1546

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 6 (2017) pp. 1538-1546**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.606.181

Modified Atmosphere with Effect of Elevated Levels of CO_2 against Cigarette Beetle (*Lasioderma serricorne* Fabricius) in Cured Turmeric Rhizomes (*Curcuma longa* Linnaeus) during Storage

K. Ravi Kumar*, C. Narendra Reddy, K. Vijaya Lakshmi, P. Radhika, K. Rameash, K. Keshavulu and B. Rajeswari

Department of Entomology, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad-500030, Telangana, India
**Corresponding author*

Keywords

Turmeric, Cigarette beetle, CO_2 and Modified atmosphere.

Article Info

Accepted:
21 May 2017
Available Online:
10 June 2017

A B S T R A C T

An experiment was conducted to study the effect of elevated levels of CO_2 by exposing the artificially infested cigarette beetle in cured turmeric rhizomes to eight different concentrations of CO_2 *viz.*, 10, 20, 30, 40, 50, 60, 70 and 80 per cent with three replications of each treatment and the efficacy of treatments was tested based on cured turmeric rhizomes infestation and population buildup of *L. serricorne*. The cured turmeric rhizomes were observed after 3, 6 and 9 months of treatment for each concentrations of CO_2 by using destructive sampling method and the data on fecundity, adult emergence and weight loss due to damage were recorded. The results revealed that exposing the cured turmeric rhizomes to 50 to 80 per cent CO_2 not only checked cigarette beetle infestation but also prevented the progeny development up to nine months of treatment.

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). 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. 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}. 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). 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.). 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). In view of serious losses in storing the turmeric form the infestation a search for the possible approaches is required. Hence, the present investigations were being taken up.

Use of modified atmosphere through the introduction of carbon dioxide (CO_2) has been considered as one of the safest methods to control storage pests. Modified atmosphere provides a way to eliminate insects from stored commodities without polluting the atmosphere and are considered as the safer traditional fumigants. No harmful residues remain after the treatment of the commodity with CO_2. Treatment with CO_2 is residue free and approved by Environmental Protection Agency (EPA), USA. CO_2 treated grains are also accepted in the organic market (Bera *et al.,* 2008).

Materials and Methods

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.

Experimental setup

Modified atmosphere studies using elevated levels of CO_2 was carried out against *L. serricorne* at ARS, Anantapur and the required concentrations of CO_2 were released into the cured turmeric rhizomes kept in 5 mm thickness polythene bags of one kg capacity with the help of carbon dioxide cylinder connected to MAP MIX gas mixer. MAP Mix 9001 ME gas mixer is PBI-Dan sensor A/S equipment for gas mixing and monitoring of gas and pressure. The MAP Mix series offers an unprecedented linearity in the flow range of 15-100 per cent and mix settings of 10 to 90 per cent. The mixer features detection of a “too low” gas inlet pressure with an alarm relay output to the external control. Mixer was connected to buffer tank with a tank volume of 15 litres and the maximum pressure was 10 bars. Buffer tank was connected to bag and tray sealer where gas was injected into the polythene bags containing cured turmeric rhizomes. After releasing the desired concentration of CO_2 into the polythene bags, they were automatically sealed by bag and tray sealer.

To study the effect of modified atmospheric CO_2 against *L. serricorne* the polythene bags were filled with 500 g of disinfested cured turmeric rhizomes and 10 pairs of freshly emerged *L. serricorne* adults were released at 10 days prior to treatment with CO_2 to ensure

uniform level of infestation. After 10 days weight of cured turmeric rhizomes were taken and CO_2 was released at eight different concentrations *viz.*, 10, 20, 30, 40, 50, 60, 70 and 80 per cent with three replications of each treatment and after releasing the desired concentration into the polythene covers they were made airtight by sealing with bag and tray sealer.

Data collection

The cured turmeric rhizomes were observed after 3, 6 and 9 months of treatment for each concentrations of CO_2 by using destructive sampling method and the data on fecundity, adult emergence and weight loss due to damage were recorded and analyzed statistically. Control was maintained by following the same procedure adopted as for CO_2 studies without exposing the cured turmeric rhizomes to CO_2 concentrations. The data were subjected to square root and angular transformation values wherever necessary and analyzed by adopting completely randomized design (CRD).

Results and Discussion

Effect of elevated levels of CO_2 against *L. serricorne* in turmeric during storage

The results on the effect of modified atmospheric CO_2 against *L. serricorne* at eight different concentrations *viz.*, 10, 20, 30, 40, 50, 60, 70 and 80 per cent are presented in tables 1 and 2.

Effect of elevated levels of CO_2 on fecundity and adult emergence of *L. serricorne*

The results on the effect of elevated levels of CO_2 on fecundity and adult emergence of *L. serricorne* in turmeric during storage are presented in table 1 and figures 1 and 2. The results indicated that the higher concentrations of CO_2 from 50 to 80 per cent were lethal to the test insect and resulted in complete mortality and did not record any fecundity under artificial infestation during nine months of study whereas in untreated control which was subjected to artificial infestation, the cigarette beetle laid 162.67 eggs after three months and it was further increased to 233.67 and 386.67 eggs after 6 and 9 months of storage, respectively. Among all the concentrations the lowest concentration of 10 per cent CO_2 was least effective and recorded 16.67, 38.33 and 68.67 eggs after 3, 6 and 9 months of storage, respectively whereas at 20 and 30 per cent CO_2 concentration recorded 9.67, 4.67 (3 MAT), 23.67, 14.33 (6 MAT) and 35.33, 21.67 (9 MAT) eggs, respectively were recorded. Though 40 per cent CO_2 recorded lowest fecundity of 1.33 by the cigarette beetle up to three months, after six months of treatment the cigarette beetle laid 6.67 eggs which further increased to 13.67 eggs after nine months of storage. The results were in agreement with the findings by Divya *et al.*, (2016) who reported that pulse beetle, *C. chinensis* exposed to CO_2 concentrations of 50 per cent CO_2 have not only minimized seed infestation but also reduced the fecundity. Caril *et al.*, (2010) reported that the results on the fecundity of the *Sitophilus. zeamais* were low when exposed to 60 and 80 per cent of CO_2 concentrations. Krishnaveni (2012) who did not noticed the fecundity of *C. chinensis* in pigeon pea seeds treated with 60 and 80 per cent CO_2 during six months of storage. Similarly Jyothsna (2014) reported that the fecundity of *C. serratus* in groundnut pods was zero when treated with 60 and 80 per cent CO_2 during six months of storage. Shivaraja *et al.*, (2012) reported that among the different concentrations of CO_2 high fecundity of pulse beetle was observed in 5 and 10 per cent CO_2 treated pigeon pea seeds.

The data on the fecundity studies revealed that the fecundity of adults was totally arrested when they were exposed to high concentrations of CO_2 (50, 60, 70 and 80 per cent) irrespective of the storage periods indicating the susceptibility of *L. serricorne* adults to high concentrations of CO_2. Press *et al.,* (1976) reported that repeated exposures to CO_2 suppressed oocyte development in the ovariole in *T. castaneum*. Dawson (1995) reported that increasing the time of exposure to 100 per cent CO_2 caused a progressive and significant decrease in fecundity during the first 40 hours. Gunashekaran and Rajendran (2005) opined that progeny production of adults of *Stegobium paniceum* and *L. serricorne* was affected by CO_2 treatment.

The adult emergence studies from the CO_2 treated cured turmeric rhizomes indicated that the CO_2 concentrations of 50 per cent and above (Table 1 and Figs. 1and 2) could able to completely check fecundity and adult emergence from the artificially cigarette beetle infested cured turmeric rhizomes while 10, 20, 30 and 40 per cent concentrations were not effective in preventing the fecundity and subsequent multiplication of pest.

At 40 per cent concentration, though the adult emergence was not observed up to three months of storage but after six and nine months of storage few adults (2.33 and 5.67, respectively) was emerged.

The highest adult emergence (285.67) was recorded from untreated control after three months of treatment which further increased to 598.67 adults after nine months of treatment. The data indicated that CO_2 concentration of 50 per cent and above was detrimental and they affected the fecundity as well as adult emergence of the test insect. Bera *et al.,* (2007) stated that all the CO_2 treatments (20 to 80 per cent) were equally effective in controlling insect population buildup of rice weevil and lesser grain borer even after twelve months of storage in rice. Caril *et al.,* (2010) reported that there was highest amount of adult emergence from the progeny at 20 per cent CO_2 concentration and decrease in the number of adult emergence at 80 per cent CO_2 concentration.

Conyers and Bell (2007) mentioned that an increase of CO_2 concentration above 20 per cent and reduction of O_2 was sufficient to eliminate the adult emergence of *Sitophilus granarius*. Carvalho *et al.,* (2012) reported that *Sitophilus zeamais* and *Sitophilus oryzae* insects exposed to high CO_2 concentrations of about 90 per cent resulted in no emergence of F_1 progeny.

Krishnaveni (2012) did not find any adult emergence of *C. chinensis* in 60 and 80 per cent CO_2 treated pigeon pea seeds even after six months of storage period. Similar findings were reported by Jyothsna (2014) who was not recorded any adult emergence of *C. serratus* at 60 and 70 per cent CO_2 concentration. Jayashree *et al.,* (2013) reported that more number of *R. dominica* adults from 10 per cent CO_2 treated sorghum seeds after 90, 180, 270 and 315 days of treatment. Similar results were reported by Shivaraja *et al.,* (2012) in pigeon pea seeds against pulse beetle. Gunashekaran and Rajendran (2005) observed the sub lethal effects of CO_2 against *Stegobium paniceum* and *L. serricorne* and they reported that treatment of adults with 30 per cent and above CO_2 concentrations caused a significant reduction in progeny production and adverse effects on the multiplication potential of the survivors.

The increase in CO_2 concentration caused decrease in the adult emergence in many insects as reported by Divya *et al.,* (2016), Jayashree *et al.,* (2013), Mohamed *et al.,* (2012), Edmund and Ho (1995) and Spratt (1979).

Table.1 Effect of elevated levels of CO_2 on fecundity and adult emergence of *L. serricorne*

CO_2 Concentration (%)	Fecundity (100 g of cured turmeric rhizomes)			Number of adults emerged (500 g of cured turmeric rhizomes)		
	3 MAT	6 MAT	9 MAT	3 MAT	6 MAT	9 MAT
10	16.67 (4.20)	38.33 (6.27)	68.67 (8.34)	14.67 (3.95)	26.67 (5.25)	55.33 (7.50)
20	9.67 (3.26)	23.67 (4.96)	35.33 (6.02)	11.33 (3.50)	15.33 (4.03)	28.67 (5.44)
30	4.67 (2.36)	14.33 (3.91)	21.67 (4.75)	3.67 (2.13)	10.67 (3.41)	23.33 (4.93)
40	1.33 (1.52)	6.67 (2.75)	13.67 (3.82)	0.00 (1.00)	2.33 (1.79)	5.67 (2.57)
50	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
60	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
70	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
80	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Control	162.67 (12.79)	233.67 (15.31)	386.67 (19.68)	285.67 (16.93)	413.67 (15.31)	598.67 (24.48)
CD(P=0.05)	0.28	0.22	0.17	0.27	0.30	0.22
SEm ±	0.09	0.07	0.05	0.09	0.10	0.07

*Figures in parentheses are square root transformed values

Table.2 Effect of elevated levels of CO_2 on weight loss by *L. serricorne*

CO_2 Concentration (%)	Weight loss (%)		
	3 MAT	6 MAT	9 MAT
10	1.09 (5.99)	3.05 (10.04)	7.82 (16.23)
20	0.96 (5.61)	1.39 (6.69)	3.29 (10.42)
30	0.32 (3.23)	1.15 (6.11)	1.86 (7.80)
40	0.00 (0.00)	0.20 (2.50)	0.68 (4.69)
50	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
60	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
70	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
80	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Control	17.86 (24.98)	38.28 (38.20)	51.03 (45.57)
CD(P=0.05)	0.39	0.99	0.82
SEm ±	0.13	0.33	0.27

Figures in parentheses are angular transformed values
MAT- Months after treatment

Fig.1 Effect of elevated levels of CO_2 on fecundity of *L. serricorne*

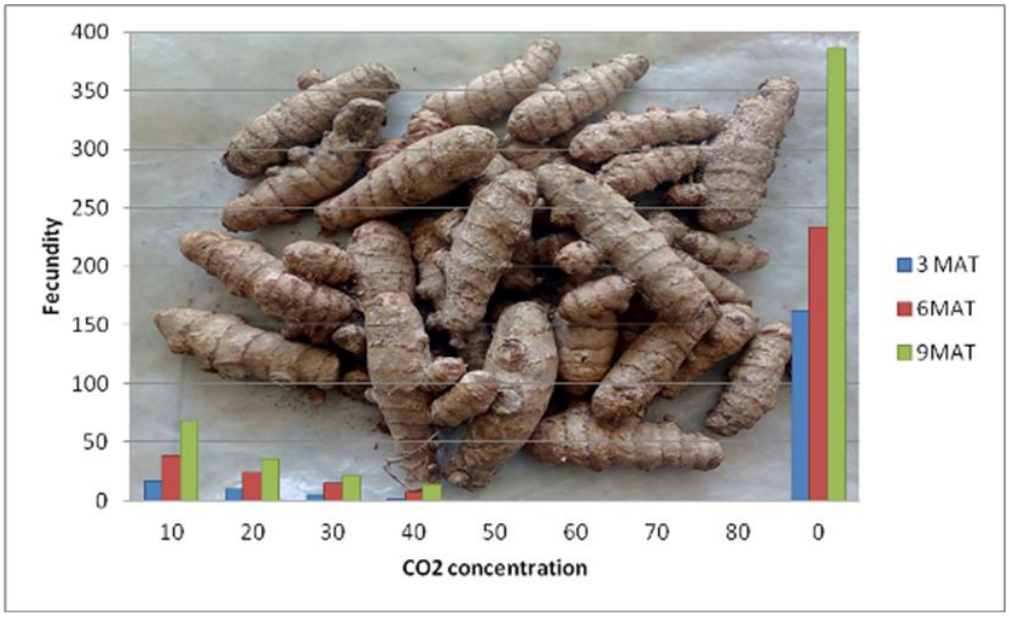


Fig.2 Effect of elevated levels of CO_2 on adult emergence of *L. serricorne*

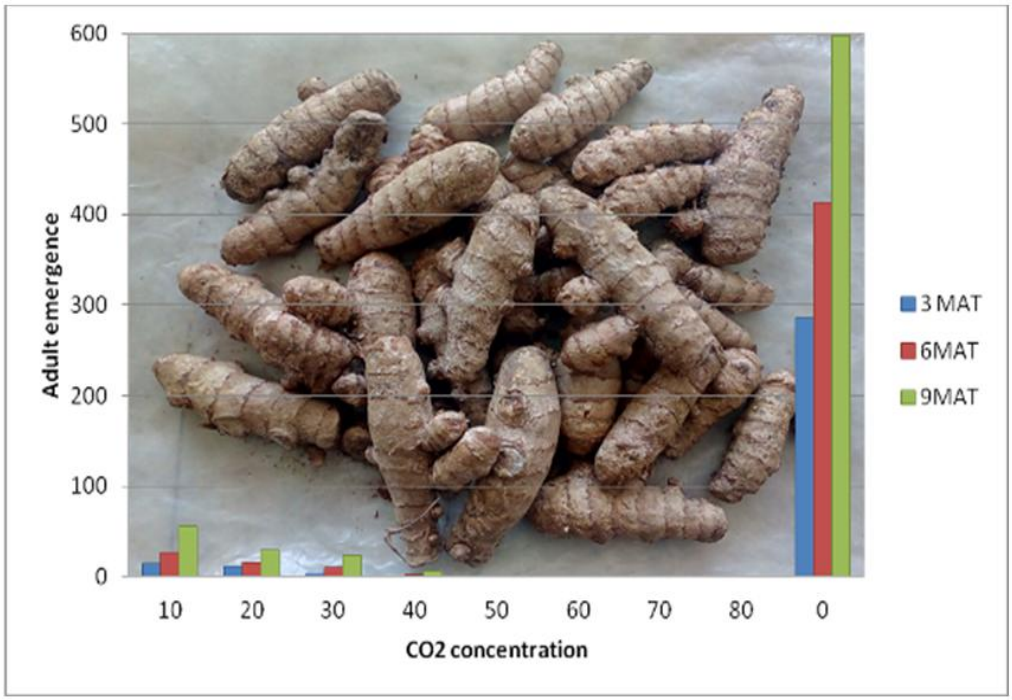
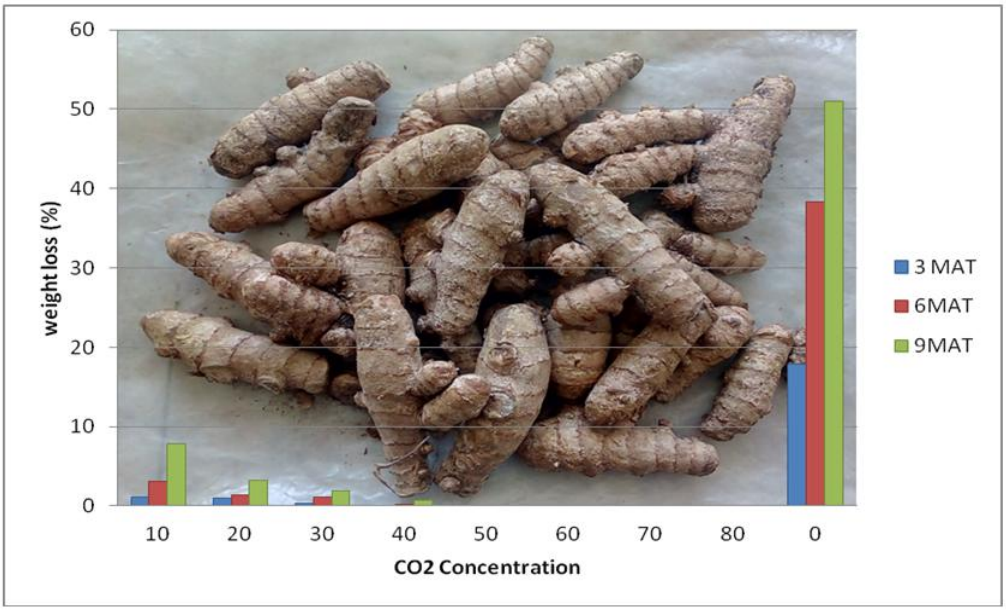


Fig.3 Effect of elevated levels of CO_2 on weight loss due to *L. serricorne*



Effect of elevated levels of CO_2 on the weight loss due to infestation by the *L. serricorne*

The results pertaining to the studies on effect of modified atmosphere with elevated levels of CO_2 on weight loss of stored cured turmeric rhizomes subjected to artificial infestation with *L. serricorne* are presented in table 2 and figure 3.

The results indicated that high concentrations of CO_2 *viz.*, 50, 60, 70 and 80 per cent did not record any weight loss even after nine months of treatment while in untreated control the weight loss was found to be 17.86 per cent after three months of treatment which increased to 38.28 per cent after six months and further increased to 51.03 per cent at nine months after treatment. Exposure of cured turmeric rhizomes to low concentration of 10, 20 and 30 per cent CO_2 treatments recorded 1.09, 0.96 and 0.32 per cent weight loss after three months of storage and it increased to 7.82, 3.29 and 1.86 per cent after nine months of storage, respectively. Exposure of cured turmeric rhizomes to 40 per cent CO_2 treatment protected the rhizomes up to three months. After six months of treatment the infestation was found to be 0.20 per cent and reached 0.68 per cent after nine months of treatment. From the results, it was evident that CO_2 concentrations of 50 per cent and above were fatal to cigarette beetle, *L. serricorne* while, 40 per cent CO_2 though controlled the pest in the initial stages and was ineffective during prolonged storage periods of six months and above.

The results were in agreement with the findings of Divya *et al.,* (2016) who reported that CO_2 concentration of 50 per cent not only checked seed infestation but also reduced the weight loss of seed compared to normal atmosphere. Jyothsna (2014) reported that CO_2 concentration of 50 per cent and above did not record any weight loss in groundnut pods. Krishnaveni (2012) who reported that 60 per cent and above CO_2 treated pigeon pea seeds did not record any weight loss by *C. chinensis* infestation up to nine months of storage. Shehata *et al.,* (2009) also stated that cowpea seeds treated with gases containing 80 per cent CO_2 showed the lowest weight

loss by *C. maculatus*. Shivaraja *et al.*, (2012) reported 9.90 per cent weight loss due to damage by pulse beetle in pigeon pea seeds treated with 10 per cent CO2 after 45 days of exposure period. Jayashree *et al.*, (2013) reported 12.50 per cent weight loss due to infestation by *R. dominica* in sorghum seeds treated with 10 per cent CO2 after 180 days of treatment while Jayashree *et al.*, (2013) reported 11.7 per cent weight loss due to infestation by *Sitophilus oryzae* in stored sorghum. Sharaf (2000) also observed that weight loss of faba bean seeds by *C. chinensis* decreased with the increasing concentrations of CO_2 and exposure periods. Yadav and Mahla (2002) reported that the effect of carbon dioxide concentrations of 50, 60, 70 and 80 per cent were found to decrease in the weight loss caused by *Trogoderma granarium* in wheat grains.

Modified atmosphere with elevated levels of CO_2 on the efficacy of different concentrations of CO_2 on infestation and population buildup of *L. serricorne* revealed that exposing the cigarette beetle infested cured turmeric rhizomes to 50 to 80 per cent CO_2 not only checked cigarette beetle infestation but also prevented the progeny development up to nine months of treatment.

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How to cite this article:

Ravi Kumar, K., C. Narendra Reddy, K. Vijaya Lakshmi, P. Radhika, K. Rameash, K. Keshavulu and Rajeswari, B. 2017. Modified Atmosphere with Effect of Elevated Levels of CO_2 against Cigarette Beetle (*Lasioderma serricorne* Fabricius) in Cured Turmeric Rhizomes (*Curcuma longa* Linnaeus) during Storage. *Int.J.Curr.Microbiol.App.Sci.* 6(6): 1538-1546.
doi: https://doi.org/10.20546/ijcmas.2017.606.181