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K Naveena
Ph.D. Scholar, Department of Agricultural Entomology Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India

R Philip Sridhar
Professor (Agricultural Entomology), Department of Agriculture School of Agriculture and Biosciences, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India

S Sheeba Joyce Roseleen
Assistant Professor (Agricultural Entomology), Department of Plant Protection Anbil Dharmalingam Agricultural College and Research Institute Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India

Corresponding Author:
K Naveena
Ph.D. Scholar, Department of Agricultural Entomology Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India

Bio - efficacy of plant powders on the mortality and adult emergence of Cigarette beetle, *Lasioderma serricorne* (Fab.) (Anobiidae: Coleoptera) infesting stored turmeric, *Curcuma longa* L

K Naveena, R Philip Sridhar and S Sheeba Joyce Roseleen

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Abstract
The leaves of neem (*Azadirachta indica)*, notchi (*Vitex negundo)*, pungam (*Pongamia pinnata)* and eucalyptus (*Eucalyptus globulus)* were shade dried, powdered and admixtured at the dosage of 250 and 500 mg along with the standard checks *viz.*, malathion 25% WP (5 mg) and deltamethrin 2.5% EC (2 µl) per 50 g of cured turmeric rhizomes. The highest percent mortality was observed in notchi leaf powder 500 mg (68.15%) followed by neem leaf powder 500 mg (66.16%), notchi leaf powder 250 mg (60.65%), eucalyptus leaf powder 500 mg (60.19%), eucalyptus leaf powder 250 mg (55.22%), neem leaf powder 250 mg (53.72%), pungam leaf powder 500 mg (47.26%) and pungam leaf powder 250 mg (43.77). The minimum number of 4.60 adults were emerged in notchi leaf powder 500 mg followed by neem leaf powder 500 mg (4.94 adults), eucalyptus leaf powder 500 mg (6.05 adults), neem leaf powder 250 mg (6.10 adults), notchi leaf powder 250 mg (6.16 adults), pungam leaf powder 500 mg (8.77 adults), pungam leaf powder 250 mg (10.27 adults) and eucalyptus leaf powder 500 mg (10.44 adults). It was evident that, notchi leaf powder 500 mg was found to be best among the plant products tested, since it caused maximum mortality and adult emergence.

Keywords: cigarette beetle, *Lasioderma serricorne*, plant products, *Azadirachta indica*, *Vitex negundo*, *Pongamia pinnata*, *Eucalyptus globulus* and turmeric rhizomes

Introduction
Turmeric (*Curcuma longa* L.) belongs to the family Zingiberaceae is also known as Indian saffron, golden spice and sacred spice. In India, it is being exported in a large scale accounting 51,500 tonnes [1]. India is the largest producer and consumer of turmeric in the world. The major states cultivating turmeric in India are Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Orissa, West Bengal and Gujarat. Andhra Pradesh is the leading state in area and production whereas the productivity of turmeric is high in Gujarat. In Tamil Nadu, Erode is one of the major turmeric growing district contributing 30 percent of India's total production [1] and also a major trading centre for turmeric in Tamil Nadu.

The cigarette beetle (*Lasioderma serricorne* Fab.) belongs to the family Anobiidae of Coleoptera is a cosmopolitan stored product pest causing considerable economic damage to stored turmeric and tobacco, hence called as cigarette beetle or tobacco beetle [3]. The larva make holes and feeds on its internal contents. Adult feeding is limited, but it make holes in packaged commodities to escape. Excreta, dead beetles and other waste products causes quality loss [5]. The economic damage caused by cigarette beetle infestation are estimated to be about 0.7–1% of the total warehoused tobacco commodity [7]. The weight loss caused by the cigarette beetle after three and six months of storage was reported to be 7.15 and 22.75 percent in turmeric [8].

To manage this devastating pest, at present aluminum phosphide is the recommended fumigant in warehouses. However, lack of practical alternatives and repetitive use led beetles to evolve phosphine resistance which further complicates the management. The residue-free disinfestation practices namely ionizing irradiation, IGR's, low temperature, low oxygen and high pressure CO_2 treatments are quite expensive and its implementation by farmers are

difficult. Since, the turmeric is one of the widely used spices for consumption, there is a need to search bio-pesticides for management. The plant products are eco-friendly, easily available, cheaper, less hazardous, easier application, delayed development of resistance and safer to consumers.

Materials and Methods

The experiment was conducted in Post Graduate Laboratory at the Department of Plant Protection, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu during 2017 - 2018. For experiments, 500 g of cured turmeric rhizomes were obtained from M/S Ulavan Producers Company Ltd., Erode. The plant products *viz.*, neem (*Azadirachta indica* A.), notchi (*Vitex negundo* L.), pungam (*Pongamia pinnata* L.) and eucalyptus (*Eucalyptus globulus* L.) leaves were collected from Horticulture Farm, HC and RI (W), Tiruchirappalli besides local procurement of malathion 25% WP and deltamethrin 2.5% EC.

The collected leaves were shade dried for a week and ground to a coarse powder with an electric blender. The powders were sieved through 60 mesh sieve and stored in an airtight plastic containers (8cm × 7cm) at 30 ± 2 °C room temperature and 60 ± 5 percent relative humidity before use. They were admixtured at the concentrations of 250, 500 mg per 50 g while malathion 25% WP was used at a concentration of 5 mg per 50 g and deltamethrin 2.5% EC at 2 µl per 50 g of well dried cured turmeric rhizomes. The powders were mixed thoroughly with rhizomes by shaking the plastic containers (11cm ×7cm). An untreated check (control) was also maintained simultaneously. The performance of the plant powders as protectants against *L. serricorne* was assessed based on the adult mortality and adult emergence due to the infestation in each treatment.

Turmeric rhizomes (50 g) and test materials at respective doses were treated and kept in plastic containers (11cm × 7cm). Five pairs of 2 to 3 days old adults of *L. serricorne* were released in each container at an interval of 6, 10, 15, 30, 45, 60 and 75 days of treatment. The plastic containers were covered with two-fold muslin cloth and tied with a rubber band to ensure ventilation. Three repetitions were used in each case. The mortality counts were recorded after 4 days of release of adults at each interval in turn to assess the efficacy of plant powders till 75 days. Insects showing movement of legs and antennae were considered as alive. The percent adult mortality was calculated on the basis of the number of dead insects as given below.

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

The corrected percentage mortality was calculated using the following Abbott's (1925) formula.

$$Corrected\ per\ cent\ mortality = \frac{P' - C}{100 - C} \times 100$$

Where, P' = Percent mortality in treatment.
C = Percent mortality in control.

For the observations on adult emergence, the number of adults emerged were recorded after 30 days of treatment till the complete emergence of adults at an interval of 10 days upto 90 days.

Table 1: Bio-efficacy of plant powders on the mortality of *L. serricorne* in turmeric rhizomes

Treatments	Mortality (%)							Grand Mean	Corrected Mean Mortality (%)
	6 DAT	10 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT		
T_1 - Neem Powder 250 mg	66.66* (54.695)^b	60.00 (50.768)^b	56.66 (48.792)^b	56.66 (48.792)^b	50.00 (45.000)^b	50.00 (45.000)^{bc}	50.00 (45.000)^{bc}	55.71	53.72
T_2 - Neem Powder 500 mg	76.66 (61.070)^b	73.33 (58.887)^b	73.33 (58.887)^b	66.66 (54.695)^b	66.66 (54.695)^b	63.33 (52.713)^b	53.33 (46.892)^{bc}	67.61	66.16
T_3 - Notchi Powder 250 mg	73.33 (58.887)^b	70.00 (56.789)^b	66.66 (54.695)^b	63.33 (52.713)^b	60.00 (50.768)^b	56.66 (48.792)^{bc}	50.00 (45.000)^{bc}	62.85	60.65
T_4 - Notchi Powder 500 mg	80.00 (63.434)^b	73.33 (58.887)^b	70.00 (56.789)^b	70.00 (56.789)^b	70.00 (56.789)^b	63.33 (52.713)^b	60.00 (50.768)^b	69.52	68.15
T_5 - Pungam Powder 250 mg	56.66 (48.792)^b	53.33 (46.892)^b	53.33 (46.892)^b	43.33 (41.149)^b	43.33 (41.149)^b	40.00 (39.231)^c	33.33 (35.244)^c	46.18	43.77
T_6 - Pungam Powder 500 mg	66.66 (54.695)^b	56.66 (48.792)^b	53.33 (46.892)^b	50.00 (45.000)^b	43.33 (41.149)^b	40.00 (39.231)^c	36.66 (37.277)^{bc}	49.52	47.26
T_7 - Eucalyptus Powder 250 mg	73.33 (58.887)^b	66.66 (54.695)^b	63.33 (52.713)^b	60.00 (50.768)^b	56.66 (48.792)^b	40.00 (39.231)^c	40.00 (39.231)^{bc}	57.14	55.22
T_8 - Eucalyptus Powder 500 mg	73.33 (58.887)^b	66.66 (54.695)^b	66.66 (54.695)^b	63.33 (52.713)^b	60.00 (50.768)^b	56.66 (48.792)^{bc}	46.66 (43.050)^{bc}	61.90	60.19
T_9 - Malathion 25% WP	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00	100.00
T_{10} - Deltamethrin 2.5% EC	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00 (89.670)^a	100.00	100.00
T_{11} - Control	0.00 (0.330)^c	10.00 (18.434)^c	0.00 (0.330)^c	0.00 (0.330)^c	10.00 (18.434)^c	0.00 (0.330)^d	10.00 (18.434)^d	4.28	0.00
SEd	9.12	8.78	9.02	8.66	8.29	6.57	7.47		
CD (0.05)	18.92	18.22	18.71	17.96	17.19	13.63	15.49		
CD (0.01)	25.71	24.77	25.44	24.42	23.37	18.53	21.06		
CV%	18.96	18.72	20.11	19.95	19.04	16.11	18.70		

Mean values followed by the same alphabet in a column are not significantly different (P = 0.01, 0.05)
*Numeric data represents the mean value of three replications
Figures in the parentheses are arc sine transformed values $\left(\sin^{-1}\sqrt{P}\right)$; DAT - Days After Treatment

Table 2: Effect of plant powders on the adult emergence of *L. serricorne* in turmeric rhizomes

Treatments	Adults emerged (no.)							Grand Mean
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	
T_1 - Neem Powder 250 mg	0.00* (0.707)	0.00 (0.707)^a	0.33 (0.912)^{ab}	1.66 (1.471)^d	2.00 (1.581)^c	8.33 (2.972)^c	24.33 (4.983)^d	6.10
T_2 - Neem Powder 500 mg	0.00 (0.707)	0.00 (0.707)^a	0.33 (0.912)^{ab}	0.66 (1.080)^{bc}	1.66 (1.471)^{bc}	5.00 (2.345)^b	22.00 (4.743)^{cd}	4.94
T_3 - Notchi Powder 250 mg	0.00 (0.707)	0.00 (0.707)^a	0.33 (0.912)^{ab}	1.00 (1.224)^{cd}	5.66 (2.483)^e	10.00 (3.240)^{cd}	20.00 (4.527)^c	6.16
T_4 - Notchi Powder 500 mg	0.00 (0.707)	0.00 (0.707)^a	0.33 (0.912)^{ab}	0.66 (1.080)^{bc}	3.66 (2.041)^d	8.00 (2.915)^c	15.00 (3.937)^b	4.60
T_5 - Pungam Powder 250 mg	0.00 (0.707)	0.00 (0.707)^a	0.66 (1.080)^b	1.00 (1.224)^{cd}	6.66 (2.677)^{ef}	14.33 (3.851)^e	39.00 (6.284)^f	10.27
T_6 - Pungam Powder 500 mg	0.00 (0.707)	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	2.66 (1.779)^{cd}	12.00 (3.535)^{de}	38.00 (6.204)^f	8.77
T_7 - Eucalyptus Powder 250 mg	0.00 (0.707)	0.00 (0.707)^a	0.00 (0.707)^a	0.33 (0.912)^{ab}	2.33 (1.683)^{cd}	8.00 (2.915)c	52.00 (7.245)^g	10.44
T_8 - Eucalyptus Powder 500 mg	0.00 (0.707)	0.00 (0.707)^a	0.00 (0.707)^a	0.33 (0.912)^{ab}	1.00 (1.224)^b	5.00 (2.345)^b	30.00 (5.522)^e	6.05
T_9 - Malathion 25% WP	0.00 (0.707)	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00
T_{10} - Deltamethrin 2.5% EC	0.00 (0.707)	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00 (0.707)^a	0.00
T_{11} - Control	0.00 (0.707)	2.00 (1.581)^b	4.00 (2.121)^c	5.00 (2.345)^e	8.66 (3.027)^f	20.00 (4.527)^f	55.00 (7.449)^g	15.77
SEd	NS	0.07	0.16	0.16	0.17	0.19	0.14	
CD (0.05)	NS	0.16	0.34	0.34	0.36	0.39	0.29	
CD (0.01)	NS	0.22	0.46	0.46	0.49	0.53	0.39	
CV%	NS	12.44	21.67	18.09	12.27	8.57	3.66	

Mean values followed by the same alphabet in a column are not significantly different (P = 0.01, 0.05)
*Numeric data represents the mean value of three replications
Figures in the parentheses are square root transformed values $(\sqrt{x+0.5})$; DAT - Days After Treatment

Results and Discussion

The data on adult mortality (Table 1) showed that the treatments differed significantly. The overall corrected percent mortality of adults ranged from 43.77 to 100 percent. The highest mortality percentage was observed in notchi leaf powder 500 mg (68.15%) followed by neem leaf powder 500 mg (66.16%), notchi leaf powder 250 mg (60.65%), eucalyptus leaf powder 500 mg (60.19%), eucalyptus leaf powder 250 mg (55.22%), neem leaf powder 250 mg (53.72%), pungam leaf powder 500 mg (47.26%) and pungam leaf powder 250 mg (43.77%) (Table 1)

While the maximum mortality (100%) was recorded by chemical insecticide treatments, among the botanical sources tested, 500 mg of notchi and neem leaf powder recorded the highest mortality of 63.33% next to chemical treatments at 60 DAT, which were also statistically on par with eucalyptus leaf powder 500 mg (56.66%), notchi leaf powder 250 mg (56.66%) and neem leaf powder 250 mg (50.00%) whereas they were superior to 250 mg of pungam and eucalyptus leaf powder besides 500 mg pungam leaf powder (40.00%). The results indicated that, even the low dosage of 250 mg of neem and notchi leaf powder were sufficient for managing *L. serricorne* for a period of two months compared to both the chemical treatments malathion and deltamethrin, which recorded 100 percent mortality up to 75 days after treatment. At this interval, the plant powders of notchi leaf at 500 mg/ 50g recorded the highest mortality (60.00%) which was statistically on par with neem leaf powder 500 mg (53.33%), notchi leaf powder 250 mg (50.00%), neem leaf powder 250 mg (50.00%), eucalyptus leaf powder 500 mg (46.66%), eucalyptus leaf powder 250 mg (40.00%) and pungam leaf powder 500 mg (36.66%), while significantly lower mortality was observed with pungam leaf powder 250 mg (33.33%) after 75 days of treatment. The efficacy of the botanical powder products tended to gradually reduce after 45 days of treatment.

The data also showed that all the treatments of plant products gave complete protection up to 40 DAT except control, while some adult emergence was noticed from 60 DAT to 90 DAT in all the plant products (Table 2). The chemical treatment did not record any emergence of beetles up to 60 DAT which was statistically on par with pungam leaf powder 500 mg (0.00 no.), eucalyptus leaf powder 500 mg (0.33 no.) and eucalyptus leaf powder 250 mg (0.33 no.). At 90 DAT, a minimum number of 15 adults were observed in 500 mg of notchi powder. No adults emerged from the two insecticidal treatments. The maximum number of adults were observed in untreated control (55.00) which was statistically on par with eucalyptus leaf powder 250 mg by registering 52.00 adults. It is inferred that, a minimum number of 4.60 adults emerged in notchi leaf powder 500 mg which was followed by neem leaf powder 500 mg (4.94 adults), eucalyptus leaf powder 500 mg (6.05 adults), neem leaf powder 250 mg (6.10 adults), notchi leaf powder 250 mg (6.16 adults), pungam leaf powder 500 mg (8.77 adults), pungam leaf powder 250 mg (10.27 adults) and eucalyptus leaf powder 500 mg (10.44 adults) (Figure 1).

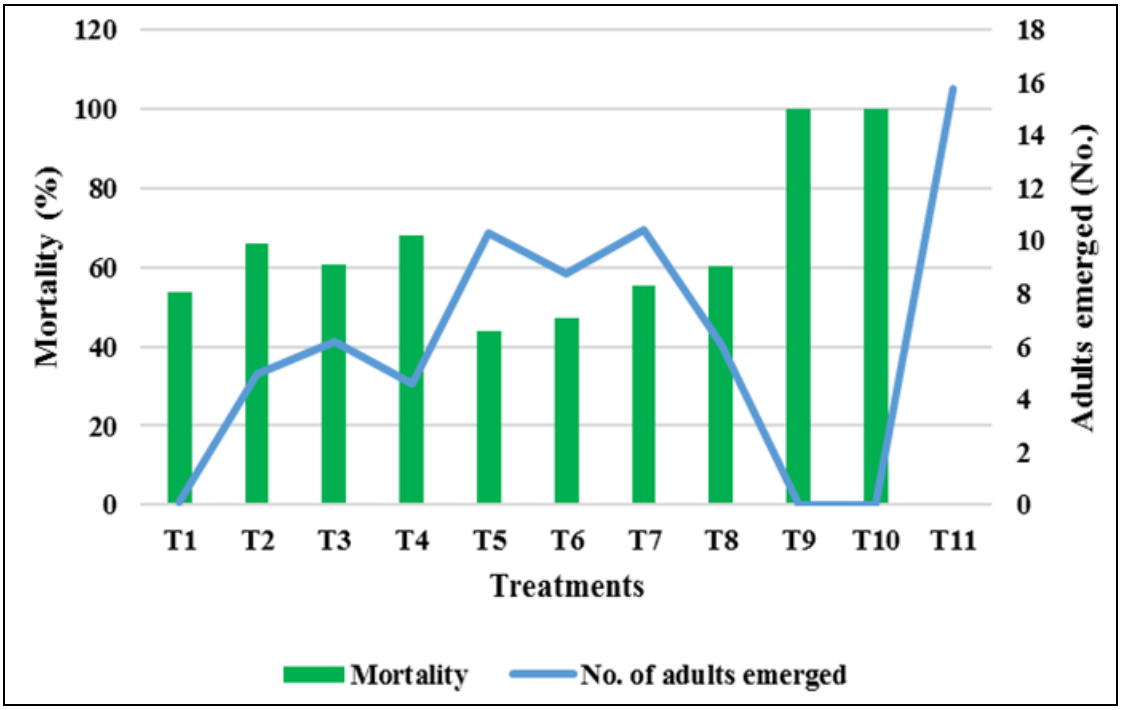

Fig 1: Effect of plant powders on the mortality and adult emergence of *L. serricorne* in turmeric rhizomes

Our present findings are in overall agreement with the findings of Ravi Kumar *et al.* (2017) [6] on the efficacy of different plant products causing lesser fecundity, adult emergence, weight loss in neem seed kernel powder after 9 months of treatment, followed by notchi leaf powder, pungam leaf powder, lantana leaf powder and annona leaf powder. Our results are also in accordance with the observations by Onu *et al.* (2015) [4] testing the plant products *viz.*, neem and garlic powders against the storage pests of *S. oryzae*, *S. zeamais* and *C. maculatus* in cereals and found that mixture of both plant products were effective, besides being in conformity to the overall results reported by Khalequzzaman and Goni (2009) [2] in confirming the efficacy of notchi leaf powder against *Callosobruchus maculatus* and *C. chinensis* in cowpea.

Conclusion Accordingly, the present study has clarified the potential for notchi leaf powder as promising botanical bio-pesticide source against cigarette beetle in stored turmeric, whereas further studies are required to optimize the dosage regime, so as to compete with synthetic insecticides.

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