

**BIO-ECOLOGY AND MANAGEMENT OF CIGARETTE
BEETLE *Lasioderma serricorne* Fab. (ANOBIIDAE :
COLEOPTERA) ON STORED SPICES**

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SEPTEMBER, 2004

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BEETLE *Lasioderma serricorne* Fab. (ANOBIIDAE :
COLEOPTERA) ON STORED SPICES**

*Thesis submitted to the
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in

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By

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SEPTEMBER, 2004

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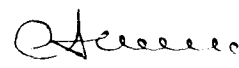
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(Vidya Hegde)

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Introduction

I. INTRODUCTION

Spices, condiments and other flavouring materials play an important role in the civilization of antiquity. India is the traditional home of spices and has through out history been associated with the trade. Spices are natural plant or vegetable products or mixture, thereof, in whole or ground form and are used for imparting flavour, aroma, pungency and seasoning of food. Indian spices are of finest quality and today the demand for them has considerably increased all over the world.

India at present is the largest producer, consumer and exporter of spices in the world. India produces more than 50 varieties of spices and exports spices to more than 120 countries in the world. The production of various spices in India today has gone upto 30.00 lakh tonnes. The area under various spices rose from 20 lakh hectare to more than 25 lakh hectares (Singhal, 2003).

Recently the export of spices is undergoing quick changes and instead of whole and bulky spices, processed materials including essential ingredients and oils are being exported. The high standard of hygienic quality is being preferred both in export as well as for domestic consumption. Presently major producing areas of different spices are located in southern states, north east, arid regions of north and hills representing wide distribution. The spices during storage and handling undergo insect and mite infestation, rodent damage besides qualitative and quantitative deterioration. The insect pests of stored spices reported to cause damage are *Lasioderma serricorne* Fab., *Stegobium paniceum* (Linn.), *Tribolium castaneum* Herbst., *Oryzophilus surinamensis* Linn., *Cryptolestis ferrugineus* (Steph), *Aracerus fasciculatus* DeGeer, *Tenebroides mauritanicus* Linn., *Carpophilus dimidiatus* Fab., *Altigenus gloriosae* Fab., *Corycera cephalonica* Staint, *Ephestia cautella* Wlk. and *Periplenata americana* Linn. Important mites associated with the spices are *Tyrophagus putrescentiae* (Schrank), *Glycephagus rurgensis* Pillai and *Acaropsis docta* (Berleese) (Jha, 1990).

Among the anobiids, *Lasioderma serricorne* and *Stegobium paniceum* have been associated from time immemorial. *L. serricorne* is virtually cosmopolitan pest infesting almost any dry product or animal matter. Srinath and Prasad (1975) observed infestation of anobiids in stored turmeric from 10 states and union territories of India to the extent of 40 per cent infestation. *L. serricorne* was adjudged as a major pest which accounted for 35.2 per cent infestation. Sudhakar and Narayan Rao (1989) reported 80 per cent damage in turmeric in Guntur district of Andhra Pradesh. Agarwal and Srivastav (1984) reported that *L. serricorne* alone is responsible for 9.73 per cent weight loss in coriander after 11 months of storage. It also attacks ginger, fenugreek, fennel, pepper, cumin, saffron, onion, garlic, chilli, peppermint, cardamom, tobacco, cocoa, rice, cowpea, mustard, aniseed etc. (Jha, 1990).

Prevention of losses in stored product due to insects is of paramount importance. For this, the study of life history, habits and habitats etc. is necessary to have thorough understanding of the situation favourable to pest and to know the weak links in the life history for the effective management of pests.

Control of *L. serricorne* populations around the world is primarily dependent on continued application of phosphine (White and Leesch, 1995). Although phosphine is effective, its repeated use for decades has disrupted biological control agents and led to outbreak of insect species, development of resistance to chemicals, undesirable effect on target and non-target organisms and environmental and human concerns. The increasing concern about its adverse effects has led to the need for the management of selective insect control alternative to fumigation.

Plant products provide alternatives to currently used insect-control agents because they constitute a rich source of bioactive agents. Much effort has therefore been

focused on plant derived potentially useful products as commercial insect control agents. Use of commercial freezer is also a promising alternative. Little work has been done to manage cigarette beetle by using plant products and low temperature methods, despite their excellent action.

Keeping these points in view, the present study was undertaken with the following objectives.

1. To study the biology of cigarette beetle *Lasioderma serricornis* Fab. on turmeric powder
2. To know the host preference of cigarette beetle to different spices
3. To assess storage losses in different spices by cigarette beetle
4. To formulate management strategies for cigarette beetle using plant products and sand
5. To study the lethal effect of low temperature on cigarette beetle

Review of Literature

II. REVIEW OF LITERATURE

Literature pertaining to biology, host preference, storage losses, management using plant products, sand and temperature regimes has been collected and presented below.

2.1 BIOLOGY OF CIGARETTE BEETLE *Lasioderma serricorne* ON TURMERIC POWDER

2.1.1 Egg

Egg of cigarette beetle is pearly white in colour (Frank *et al.*, 1957; Retief and Nicholas, 1988; Narasimha Rao *et al.*, 2003) and oval in shape with a slight swelling in the middle and bluntly rounded. On one end of the chorion a blunt spine like projection was observed by Narasimha Rao *et al.* (2003).

Frank *et al.* (1957) studying on tobacco pointed out that egg of cigarette beetle was elliptical, whitish, becoming, opaque and dull just before hatching. The general appearance was smooth without any reticulation except for a portion at the end from which the larva emerged, which had numerous spines. The average length and width were 0.45 mm and 0.21 mm.

According to Howe (1957) incubation period of *L. serricorne* ranged from 8.1-8.9 days at 27.5°C and 30 per cent RH on wheat. It was around 7 days on stored tobacco (Sivik *et al.*, 1957). Kismali and Goktay (1988) observed that the incubation period on ground and leaf tobacco were 7.9 and 7.1 days, respectively at 27±1°C and 70-80 per cent RH. Eggs hatched after 5-8 days at 32°C and 72.5-80.5 per cent RH (Allotey and Unanaowo, 1994).

2.1.2 Larva

Canzanelli (1935) reported four larval instars, the first three instars were approximately equal in length and the last was about twice as long. More larval mortality was recorded in the first instar. In the absence of any other food, the newly hatched larva may eat the egg shell and the larval period was 43-68 days at 22.5°C and 50 per cent RH (Howe, 1957).

Sivik *et al.* (1957) studied the biology and reported that the newly hatched larva was less than 1 mm in length and the body was covered with fine hairs with yellowish head and semitransparent whitish body. Fine particles of tobacco, dust and frass on the minute hairs on the body imparted brownish colour. This was especially noticeable in last instar. When disturbed, the larva assumed curled attitude and abdomen bent round. Full grown larva measured about 0.16 inch length. The average larval period was about 40 days and 4-5 larval instars were noticed.

Narasimha Rao *et al.* (2003) observed that there were four larval instars on stored tobacco. First instar larva was creamy white in colour and possessed few hairs on each segment. The second instar larva was also creamy white in colour with a dense cover of hairs which were slightly yellow in colour, soon after they possessed long hairs. The full grown fourth instar grub was scarabeiform with dark head and with thick brown hairs on the body.

2.1.3 Pupa

Fully grown larva stops feeding and forms a pupal cell or cocoon, usually fastened to firm surface (Howe, 1957). The cell was made of food and waste material cemented together by a secretion produced by the midgut (Van Emden, 1929). Soon after completing the cell, larva became a pre-pupa and casted the larval skin after 2-4 days at

30°C in the cell. Pre-pupal stage varied in different conditions. In the quiescent pupal period, the adult remains in the cell and became sexually mature. This stage can withstand low temperature for considerable time (Howe, 1957).

The newly formed pupa was glossy white but gradually turned to reddish brown after few days. Within the pupal cell, the pupa laid on its back with the legs, wings, eyes and other external features of the adult being readily apparent. The pupal skin frequently adhered to the tip of the abdomen for short period of time after adult emergence. The pupal period was about 5 days (Sivik *et al.*, 1957).

The pupal period varied between 4-12 days. Emergence from the pupa was noticed mainly during night time (Samuel *et al.*, 1984). Sex determination of the pupa can be done by examining of the genital papillae. These organs are globular and not projecting in males, while they are 3 segmented and divergent in the females (Halstead, 1963; Narasimha Rao *et al.*, 2003). Runner (1919) and De Bussy (1917) recorded the pupal period of five days whereas according to Jones (1913) it was four days.

2.1.4 Adult

The adult beetle was small (2.0-3.7 mm) (Retief and Nicholas, 1988) weighed 1.6 to 4.4 mg and light to dark brown in colour (Anon., 1972; Klein, 1986), although a blackbody colour mutation has been reported (Coffelt and Vick, 1973).

Colour and size of the insect depends upon type of food, temperature and humidity encountered during the development (Anon., 1972). Although size of adult was affected by the quality of larval food (Jones, 1913), larger beetles tend to be females (Lefkovitch and Currie, 1963) and Howe (1957) and Klein (1986) reported that the adult beetle was oval, with the head and prothorax bent downward giving the insect a humped convex appearance. The head is deflexed and is almost completely obscured from

above. The elytra are not striated and appear rather smooth. The antennae are serrate, with a saw-like appearance and are the same thickness from base to tip. Tarsal formula was 5-5-5. Adult mandible are some what triangular, with two apical teeth and no molar projection (Klein, 1986).

Sivik *et al.* (1957) recorded the period of greatest activity usually between 4:30 pm and mid night. The beetle rests with the head and prothorax bent downwards. It shows feigns death by withdrawing legs when disturbed. The adults feed very little, and in the summer lived for a week or more. The antennae were serrate and body humped, covered with fine hairs (Narasimha Rao *et al.*, 2003).

2.1.5 Adult longevity

Adult longevity was 2-7 weeks on stored wheat (Howe, 1957). Longevity of newly emerged adult on cowpea was 22.56 days for male and 26.52 days for female. Adult longevity for male and female on rice, groundnut, maize, wheat and sorghum were 26-64 days and 33.24 days, 24.04 days and 31.72 days, 26.0 days and 30.84 days, 24.64 days and 27.68 days and 25.96 days and 30.72 days respectively (Allotey and Unzanaowo, 1994).

Farag and Ismail (1985) found that the adult longevity of *L. serricornis* was short with a maximum period of 25.9 days. Mated females have shorter life span than unmated ones. Males have shorter life span than females. The life span of adult beetle depends on the food on which they were consumed (Cline and Highland, 1985).

2.1.6 Oviposition

Pre-oviposition period of *L. serricornis* was 2-3 days at 26.5°C and 70 per cent RH (Bare *et al.*, 1947). Dick (1937) recorded oviposition period of 6-8 days at 27°C and 73 per cent RH and eggs were laid singly in crevices, folds or depression in the food.

In uncontrolled condition, the pre-oviposition period has been recorded to be 1-3 days (Stamatinis, 1935), 2 days (Canzanelli, 1935), 2-5 days (Jones, 1913), 2-6 days (Runner, 1919), 4-5 days (Ustinov, 1932) and few up to 10-13 days (Skalov, 1931).

According to Shepard (1943) the beetles need hard surface for oviposition. Dick (1937) stated that oviposition continued for 6-9 days at 27°C and Powell (1931) recorded 3-10 days at 32°C, while the longest period of 21 days was recorded by Runner (1919). Howe (1957) reported that individual female laid eggs for 6-9 days at 35°C, 7-10 days at 30°C, 11-18 days at 25°C and 14-20 days at 22.5°C. Stamatinis (1935) recorded oviposition period of 4-14 days whereas Skalov (1931) recorded oviposition periods of 8-15 days and according to Jones (1913) it was 6-8 days.

2.1.7 Fecundity

Number of eggs per female was 27-32 (Runner, 1919), 43.6 (Powell, 1931), 69-3 (Skalov, 1931), 38.6 (Stamatinis, 1935), (Ustinov, 1932), 20 (Shibuya and Yamada, 1935), 76.1 (Dick, 1937), 30 (Vanderveen, 1940) and 40-75 (Atkinson, 1986).

Yadav and Tanawar (1986) studied fecundity of *L. serricornis* on turmeric and found that the average number of eggs collected from each pair to be 109. Allotey and Unanaowo (1994) studied the fecundity of *L. serricornis* and found 14.24, 18.48, 24.52, 37.44, 40.2 and 42.72 on rice, cowpea, groundnut, maize, wheat and sorghum, respectively. Narasimha Rao *et al.* (2003) recorded 968 eggs by 25 pairs of cigarette beetle in stored tobacco.

2.1.8 Sex ratio

There were no marked deviation from a sex ratio of unity (Howe, 1957). The sex ratio of male to female was 1:1 (Sivik *et al.*, 1957), 1:1.33 (Bhalodia and Chari, 1976), 1:2 (Rao, 1978) and 1:1.18 (Narasimha Rao *et al.*, 2003).

2.2 HOST PREFERENCE STUDIES OF CIGARETTE BEETLE

Howe (1957) observed mean development period of 26.1 days in *L. serricornis* feeding on wheat at 30°C and 70 per cent R.H. followed by 26.5-31.6 days on cotton seed and coconut meals with yeast powder and whole cowpea. Development was fairly rapid (33-34 days) on whole garden peas, groundnut and crushed locust beans but it lasted 55.2, 68.5 and 105.6 days on crushed cocoa beans, whole locust beans and whole cocoa beans respectively.

El-Halfway and Nakhla (1973) observed the effect of diet on the development and longevity of *L. serricornis* at 30°C and 70 per cent RH. The duration of the various life stages was affected by the diet. Development period from oviposition to the end of the pupal period was longest on coriander followed by rice, maize and chickpea. The adult life span was shortest on coriander followed by maize, rice and chickpea indicating the least suitability of the coriander flour diet.

El-Halfway and Nakhla (1976) further observed that larval development of *L. serricornis* was fastest at 30°C and 70 per cent RH on dried onion than on wheat flour. Pupal stage was unaffected while the adult survived for longer duration. Dried onion was suitable diet.

Bhalodia and Chari (1976) studied the bionomics of *L. serricornis* on different diets at different temperatures. At variable temperature, egg to adult period lasted 46-47 days on mixture of wheat flour and yeast, 39-84 days on VFC tobacco powder and 67-85 days on VFC tobacco seeds. Total developmental period on wheat flour + yeast was 44-58 days at 31.0±0.5°C.

Bhattacharya *et al.* (1977) observed no development of *L. serricornis* on undamaged soybean seed but 79 per cent emergence was recorded in soybean flour.

Emergence improved upto 99-100 per cent by the addition of either yeast, wheat flour or green gram flour and also by autoclaving for 30 minutes.

Lecato (1978) studied the infestation and development of newly hatched larvae of *L. serricorne* in closed spice cans. Out of 18 spices, 14 were infested but no infestation was observed after 6 months incase of cinnamon, cloves, east Indian mace and nut meg. Cayenne pepper, paprika, curry powder and chilli powder exhibited highest infestation. Adult emergence was observed to be 70, 71, 122 and 135 days after infestation in paprika, cayenne, pepper, curry and chilli powder respectively. Eight-five and 72 per cent adult emerged in cayenne pepper and paprika respectively but only 2 per cent emerged in curry powder and chilli powder.

Yadav and Singh (1985) studied host suitability of lentil flour for eight stored product insects. The development of *L. serricorne* and *S. paniceum* on lentil flour required two times longer duration as compared to wheat flour.

Yadav and Tanwar (1986) evaluated the suitability of rearing medium for growth and development of *L. serricorne*. Turmeric powder was used with wheat flour in the ratios of 2:8, 3:7 and 5:5. Among the 3 mixtures, turmeric and wheat flour (2:8) were found to be the best medium for the development of *L. serricorne*.

Burcea (1986) reared *L. serricorne* for 5 successive generations on 12 diets at 24 and 30°C. Maize meal with dried yeast mixed in the ratio of 93:7, whole wheat flour, peppermint, chamomile (*Matricaria chamomilla*, *Chamomilla recutita*), tobacco, lime flowers, St. John's wort (*Hypericum perforatum*), sweet and hot paprika (*Capsicum annum*); cocoa powder, dehydrated apples. All of these diet allow the insects to survive and reproduce. The development time was longest (159.4 days) on hot paprika at 24°C. while least (61.3 days) on maize meal with yeast at 30°C.

Jha and Yadav (1994) studied host suitability of spice mixture to *L. serricornis*. Wheat flour and 5 powdered spices viz., fennel, chilli, coriander, cumine and black pepper and ethanol, petroleum ether extracted fennel and chilli were mixed in the ratio of (8:2). Petroleum ether extracted fennel exhibited highest growth index value of 0.095 and was the most suitable combination for development of *L. serricornis* at 55 per cent RH. The order of suitability in descending order for other spice mixtures was fennel (0.094), chilli (0.092), coriander (0.083) ethyl alcohol extracted chilli (0.080), cumin (0.079), ethyl alcohol extracted fennel (0.060), petroleum ether extracted chilli (0.055) and black pepper (0.052).

At 60 per cent RH out of 27 spices tested *L. serricornis* developed only in four spices. Higher per cent development was observed in white poppy seed followed by ginger, nigella and garlic. The per cent development was 56.7, 13.3, 6.7 and 3.3 respectively. The mean development period was 49.2, 54.2, 55.6 and 69.0 days, respectively. On the basis of highest development and shorter development period, white poppy indicated host suitability of *L. serricornis* (Jha and Yadav, 1996).

2.3 STORAGE LOSSES IN DIFFERENT SPICES BY CIGARETTE BEETLE

Agarwal and Srivastava (1984) studied storage losses in coriander by cigarette beetle 11 months after storage. The moisture content ranged from 12.00 per cent to 14.17 per cent in control, while it ranged from 12.00 to 16.25 per cent in infested coriander and average population of insect recorded was 867 after 11 months of storage. Total loss in weight was 9.73 per cent in infested coriander, while 0.43 per cent was found in control.

Agarwal *et al.* (1981) conducted an experiment to know storage losses in turmeric by *L. serricornis*. Moisture content decreased from 12.5 to 9.8 per cent in control, which

decreased from 12.5 to 12.00 per cent in infested rhizome after 7 months of storage and average population of insect recorded was 292 adults. Total loss in weight was 8.85 per cent after 7 months of storage.

Srinath and Prasad (1975) stated that rhizomes of turmeric infested by *L. serricornis* were light in weight, presented characteristic holes externally as visible sign of adult emergence. About 3 to 30 larvae were recorded with an average of 13 larvae per rhizome.

Vijayalaxmi *et al.* (1990) reported weight loss due to cigarette beetle infestation, which varied from 0.68 to 3.42 per cent in case of rhizomes after 6 months of storage.

2.4 MANAGEMENT OF CIGARETTE BEETLE USING PLANT PRODUCTS AND SAND

Literature pertaining to management of cigarette beetle using plant product is limited. Hence, effect of plant products on other coleopteran pests has been reviewed and presented.

Over 90 per cent mortality at 3 days after treatment was achieved with an extract of *Acorus calamus* var. *angustatus* rhizome against cigarette beetle and it was found to have fumigant action (Kim *et al.*, 2003).

Jilani (1984) reported *A. calamus* to be a good grain protectant against *Rhizopertha dominica* (Fab.), *Sitophilus oryzae* (Linn.), *Sitotroga cerealella* (Oliv.) and *Calasobruchus analis* (Fab.) at 1, 0.5 and 0.25 per cent respectively, in wheat and mung grains. None of the species of insect could emerge from treated grains.

Siva Srinivasu (2001) observed cent per cent mortality at 7 days after beetle release and no grain weight loss was reported with sweet flag powder at 1 per cent in jowar grains against *S. oryzae* during 90 days of storage period.

Shivanna (1988) found sweet flag to be good in controlling *Callasobruchus chinensis* (Linn.) activities in redgram, the mortality of beetles at 24, 48 and 72 hours after release (HAR) being 50, 50, 70 per cent, 63.33, 76.67, 88.33 per cents and 76.67, 80.00, 100 per cent at 0.5, 1.5 and 2.5 g per 50 g seeds, respectively as against no mortality observed in control. Further mean number of eggs laid at 0.5, 1.5 and 2.5 g per 50 g seeds were 8.00, 6.67, 0.00 respectively, mean number of adult emergence was 0.00, 0.00 and 0.00 and weight loss was 0.00, 0.00, 0.00 per cent respectively as against 276.33 eggs were laid, 260.0 adult emergence and 17.89 weight loss was observed in control. Considering cost benefit ratio, sweet flag at one kg per quintal of grains was found to be best for offering good protection to red gram from *C. chinensis*.

Kittur (1990) noticed the mortality of *C. chinensis* at 24, 48 and 72 HAR to be 90, 100, 100 per cent, 90, 100, 100 per cent and at 0.5, 0.75 and 1.0 per cent sweet flag rhizome powder in red gram seeds, respectively as against no mortality in control. Pandey *et al.* (1976) reported that 1 to 2 parts of powdered sweet flag rhizomes to be effective in protecting the gram seeds from damage by bruchid for at least 135 days.

Sweet flag (2%) and neem seed kernel powder (2%) were found to be effective in controlling *S. oryzae* in maize grains. The mortality of weevils at 7, 14, 21 and 28 days after release were cent per cent and population buildup was also nil at 30, 60 and 90 days after release. In case of lakke leaf powder at 5 per cent treatment, adult mortality was 60.00, 66.25, 72.75 and 82.50 per cent and population buildup were 25.00, 94.00 and 197.00 at 7, 30, 60 and 90 days after release (Yevoor, 2003).

Sharma (1995) tested neem seed kernel powder at low dose (2 per cent w/w) which was found to be effective against *S. oryzae* in the protecting maize seeds for two weeks. A higher concentration of this powder (10% w/w) was effective against *R. dominica*, *T. castaneum* and *T. confusum* over large period of time.

In the study of Qadri (1973), custard apple seed extract showed to possess more olfactory repellency against normal susceptible strain of *S. oryzae* and *T. castaneum*. Banerji and Nigam (1985) observed the rotenone like effect in the seeds of custard apple. The seed powder of custard apple at 5 parts per 100 parts of greengram resulted in 100 per cent mortality of *C. analis* after 3 days of treatment and completely prevented the female from egg laying until 60 days after treatment. Furthermore no population buildup and grain damage were observed until four months of storage (Juneja and Patel, 1994).

Radhakrishnan *et al.* (1983) opined that in red gram seeds the per cent mortality of *C. chinensis* was 68.9 and the per cent weight loss in red gram seed was 7.8 as compared to 19.2 per cent in control when neem seed kernel powder was tested at 10 g per kg of seeds. Sowumni and Akinnusi (1983) reported that neem seed kernel powder one and two parts per 100 parts of cowpea seeds was found to be effective for eight months against *C. maculatus*.

Neem seed powder at 0.5, 1.5 and 2.5 g per 50 g seeds was found to be effective in controlling *C. chinensis* beetle in redgram. The mortality of beetles at 48 and 72 HAR reached 30.00, 30.33 and 40.67 per cent, respectively, during first generation as against no mortality in control. The mean adult emergence and mean per cent weight loss at these dosages were found to be 48.67, 41.33, 22.67 and 2.09, 2.03, 1.48 per cent respectively as compared to 276.33, 26.00 and 17.89 per cent in control. The cost benefit ratio of neem seed powder at 1.00 per cent of grain was found to be most economical (Shivanna, 1998).

According to Sowumni and Akinnusi (1983), neem seed kernel powder one to two parts per 100 parts of cowpea seeds was found to be effective for eight months against *C. maculatus*.

The neem bark powder contains insect growth regulating and insecticidal properties and effectively controls the increase of population of *C. chinensis* on chickpea

in storage (Pandey and Singh, 1997). Neem seed powder @ 5 per cent caused cent per cent mortality of rice weevil at 7 days after beetle release and weight loss was nil during 90 days of storage (Siva Srinivasu, 2001).

Krishna Prasad (1977) reported cent per cent mortality of *C. chinensis* on cowpea seeds even four months after treatment with neem seed powder at 1:100 parts by weight. Good results were obtained by Sharadamma *et al.* (1977) on paddy seeds against *Tribolium granarium* when treated at one and two per cent neem seed powder. In black gram at 1.5 per cent concentration, 19.5 per cent adult mortality of *C. chinensis* has been reported by Mathur *et al.* (1985) as against 10.23 per cent in control.

The mortality of beetles at 24, 48 and 72 HAR were found to be 0.00, 0.00, 43.33 per cent, 0.00, 0.00, 50.00 per cent, 0.00, 20.00, 50.00 per cent respectively at 0.5, 1.0 and 2.0 per cent of neem seed kernal powder, as against no mortality in control (Kittur, 1990).

Mishra *et al.* (1992) reported that *Vitex negundo* leaf powder @ 5 per cent in wheat grain caused 80.00 per cent mortality of *S. oryzae* at 30 days after treatment. Per cent damaged grains, weight loss and population build up during 90 days of storage were 19.7, 12.7 and 29.00 respectively. Leaf powder extract of *V. negundo* at 5 per cent resulted in 96.34 per cent mortality of *S. oryzae* 30 days after treatment and than onwards effectiveness gradually reduced as reported by Biradar (2000).

Among the plant products tested, sweetflag rhizome powder at 0.6 per cent caused cent per cent mortality of *S. oryzae* and *R. dominica* which gave complete protection upto 240 days. This product completely prevented F₁ progeny and there was no loss in grain weight. Sweetflag even at 0.5 per cent caused 100 per cent adult mortality of *T. castaneum* and *C. pusillus*. Custard apple seed powder (1.4%) was found to be moderately effective against for above four species. However, neem seed powder was least effective (Kalasagond, 1998).

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Tamarindus indica L. and *Vinca rosea* L. leaves were found to have almost 100 per cent repellent action both in fresh as well as dried form against adults of *L. serricornis* under laboratory conditions (Ambadkar and Khan, 1994).

Custard apple seed powder @ 5 per cent in rice and wheat grains showed cent per cent mortality of *S. oryzae* at 7 days after beetle release and recorded the no weight loss at 90 days after storage (Siva Srinivasu, 2001).

Application of sand in India is an age old practice to protect stored grain from insect attack (Pruthi and Singh, 1950). Sand at 30 per cent effectively prevented the infestation by *S. zeamais* and *S. cerealella* in maize (Golob *et al.*, 1982); mortality of adults of *C. chinensis* at 24, 48 and 72 HAR was recorded to be 10.00, 13.33, 20.00 per cent, 13.33, 33.33, 26.66 per cent and 20.00, 26.66, 33.33 per cent at 20, 30 and 50 per cent sand in redgram seeds as against no mortality in control by Kittur (1990).

Sand at 30 admixture were found to be less effective treatment against *S. oryzae* and *R. dominica*. Adult mortality of *S. oryzae* ranged from 38.33 to 58.33 per cent at 240 days after treatment and 51.66 to 55.00 per cent mortality of *R. dominica* at 60 to 240 days after treatment (Kalasagond, 1998).

2.5 LETHAL EFFECT OF LOW TEMPERATURE ON CIGARETTE BEETLE

At -4°C for 7 day exposure all the stages of *L. serricornis* were killed (Tenhet and Bare, 1951), at 0°C for 14, 13 and 12 day exposure killed pupa, adult and larva respectively (Swingle, 1938), at 4.5°C for 33 days killed all the stages (Swingle, 1938; Tenhet and Bare, 1951) and at -10°C for 7 day killed all the stages (Runner, 1919), -5 to 0°C for 5 days exposure killed all larvae, pupae and adults of *L. serricornis* (Keuchenius, 1917).

Material and Methods

III. MATERIAL AND METHODS

Studies on the cigarette beetle, *Lasioderma serricorne* Fab. with reference to biology, host range, storage losses, management with plant products and low temperature effect were carried out at Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad, Karnataka during 2003-04. The various materials and techniques employed to achieve each objective are presented below.

3.1 STUDIES ON LIFE HISTORY OF CIGARETTE BEETLE UNDER LABORATORY CONDITIONS

3.1.1 Maintenance of stock culture

The adult beetles of *L. serricorne* were collected from infested chilli powder. The culture was maintained on rearing medium of turmeric and wheat flour (2:8) in the container (Jha and Yadav, 1994). The mouth of the container was closed with muslin cloth and fastened with rubber band, fresh rearing medium was introduced periodically for proper development of beetles and culture so maintained was used in experiments aimed to meet out the objective.

3.1.2 Pure culture

The pure culture of cigarette beetle was raised by infesting insect free turmeric powder with freshly emerged single mating pair in plastic jar.

3.1.3 Collection of eggs

An apparatus consisting of plastic jars (9 cm diameter and 14 cm deep) were used as a oviposition cage for *L. serricorne* (Allotey, 1985; Allotey and Goswami, 1990). Each jar contained 10 pairs of newly emerged adult from stock culture raised on the standard medium. The jar was inverted over a glass petridish (10 cm dia.) lined with carbon paper

at the base, which provided a rough surface for oviposition as well as contrast to the white colour of the eggs. Uncollapsed eggs were collected daily with a camel hair brush no.1 for experimentation.

3.1.4 Egg hatchability and incubation period

Ten uncollapsed eggs about 24h old were placed in a glass petriplate (10 cm dia.) containing finely sifted turmeric powder to provide a ready source of food, to reduce risk of the newly hatched larvae feeding on unhatched eggs. Twenty-five replicates were prepared. Examination of the content of the petridishes were undertaken daily using microscope for recording incubation period. Hatched and unhatched eggs were counted and percentage egg hatchability recorded.

3.1.5 Larval and pupal period

On hatching, 25 larvae of cigarette beetle were allowed to feed individually in separate test tubes containing turmeric powder, larval instars were determined by the presence of moulted skin and size of head capsule width. Head capsule width was measured by using stage and Ocular Micrometer. Pupal period was also recorded.

3.1.6 Ovipositional studies

Freshly emerged adult beetles were collected in a specimen tube. After mating, the females were removed and enclosed individually in a glass tubes with turmeric powder for oviposition. Ten such tubes were maintained separately. Turmeric powder was replaced every day and examined under microscope to record pre-ovipositional period, fecundity and adult longevity.

3.2 HOST PREFERENCE STUDIES OF CIGARETTE BEETLE

Different spices viz., coriander, chilli powder, turmeric powder, fennel, cumin, ajowan and black pepper were procured from the market.

The details of collection of eggs was as mentioned in 3.1.6. The eggs were transferred to standard medium for hatching. Sample spices (0.50 to 1.5 g) were transferred to glass vials (5 x 1 cm dia.) and freshly emerged 10 larvae were released in each vial. The open end of each vial was plugged with cotton. The per cent adult emergence and mean developmental period (MDP) were determined three replications were maintained. Data were subjected to statistical analysis. Growth index (GI) values were calculated as suggested by Howe (1971) as follows.

$$\text{Growth index (GI)} = \frac{\log_e s}{T}$$

Where,

\log_e = natural log *i.e.*, 2.30259

s = survival or per cent adult emergence

T = Time or developmental period in days

3.3 STORAGE LOSSES IN DIFFERENT SPICES BY CIGARETTE BEETLE

Different spices, *viz.*, coriander, chilli powder, turmeric powder, fennel, cumine, ajowan and black pepper were selected for the study.

About 150 g of each spice was taken in plastic bottle and 10 pairs of freshly emerged beetles were released. Open end of the bottle was fastened with muslin cloth and rubber band. Observations were recorded at three and six months after release of adults on insect population buildup, per cent weight loss and per cent moisture content. Data were subjected to statistical analysis. Per cent weight loss was calculated using formula as follows.

$$\text{Weight loss (\% in grams)} = \frac{\text{Initial} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.4 MANAGEMENT OF CIGARETTE BEETLE USING PLANT PRODUCTS AND SAND IN DIFFERENT SPICES

3.4.1 Selection and processing of plant products

Details of plant products evaluated against *L. serricornis* are given in Table 1.

3.4.2 Processing of plant products and sand

- a. **Leaves:** The leaves of lakke, tamarind, periwinkle and neem, were shade dried and ground into powder which were then sieved through 60 micron mesh.
- b. **Seeds:** the mature seeds of neem, custard apple were dried at 30°C in oven separately and ground to powder and sieved.
- c. **Rhizomes:** The matured rhizomes of sweetflag were chopped into pieces and dried at 30°C in oven and ground to powder and sieved through 60 micron sieve.
- d. **Sand:** It was sieved through 60 micron sieve and properly washed with fresh water and sun dried.

Each of the plant products and sand at the desired dosage (Table 1) was thoroughly mixed with 100 g of spices in a plastic bottle.

Freshly, emerged beetles were drawn from the stock culture and released at the rate of 10 pairs per bottle. Each treatment was replicated three times. The observations on adult mortality at 5, 10 and 15 days after release, adult emergence and per cent weight loss at 60, 90 and 120 days after release were recorded. Data were subjected statistical analysis.

Table 1. List of plant products evaluated against *L. serricorne* on different spices

Sl. No.	Plant species	Common name	Family	Plant part used	Dosage (%) (w/w)
1.	<i>Azadirachta indica</i> A. Juss.	Neem	Meliaceae	Seed	2.0
2.	<i>Acorus calamus</i> L.	Sweet flag	Araceae	Rhizome	0.5
3.	<i>Vitex negundo</i> L.	Indian Privet (Lakke)	Verbenaceae	Leaf	5.0
4.	<i>Tamarindus indica</i> L.	Tamarind	Fabaceae	Leaf	5.0
5.	<i>Vinca rosea</i> L.	Periwinkle	Apocynaceae	Leaf	5.0
6.	<i>Azadirachta indica</i> A. Juss	Neem	Meliaceae	Leaf	5.0
7.	<i>Annona squamosa</i> L.	Custard apple	Annonaceae	Seed	5.0

3.5 LETHAL EFFECT OF LOW TEMPERATURE ON CIGARETTE BEETLE

Ten gram of turmeric powder containing larva, pupa and adult (10 each stage) were exposed separately to low temperature range of 4°C, 0°C, -4°C, -18°C and room temperature. Three replications of each stage were maintained. The exposure period ranged from 4 h, 2 days, 4 days, 6 days, 8 days and 15 days for all the stages. Observation on per cent mortality was recorded.

Experimental Results

IV. EXPERIMENTAL RESULTS

Results of the investigation on the cigarette beetle *Lasioderma serricorne* Fab. with reference to biology, host preference, storage loss, management using plant products, sand and lethal effect of low temperature regimes carried out during 2003-04 at the Department of Agricultural Entomology, UAS, Dharwad are presented in this chapter.

4.1 BIOLOGY OF CIGARETTE BEETLE UNDER LABORATORY CONDITIONS

Biology of cigarette beetle on turmeric powder was studied in the laboratory during 2003-2004. The results along with description of brief external morphology of various developmental stages are furnished here under.

4.1.1 Egg

The eggs were elliptical in shape and reticulated at one end and were laid singly on the surface of turmeric powder. Freshly laid eggs were translucent and white in colour and became opaque before hatching. The incubation period ranged from 7 to 9 days (Table 2) with a mean of 8.00 ± 0.74 days (Plate 1).

4.1.2 Larva

The grub passed through four instars (Plate 2).

First instar larva

First instar larva is creamy white with light yellow tinge with head narrower than thoracic segments, the anterior rim of the mandible is dark brown in colour. Thoracic segments are wider than abdominal segments. Body with small fine hairs to which frothy materials adhere. Abdomen is ten segmented, broader in the middle and narrower

Table 2. Biology of cigarette beetle *L. serricorne* on turmeric powder

Sl. No.	Difference stages	Duration (days)	
		Range	Average±SD
1.	Incubation period	7-9	8.00±0.74
2.	Total larval period	32-41	36.50±3.32
	First instar	7-9	8.00±0.77
	Second instar	8-10	9.00±0.89
	Third instar	8-11	9.50±1.10
	Fourth instar	9-11	10.00±0.93
3.	Pupal period	6-11	8.50±1.80
4.	Total life cycle	57-79	68.00±3.19

SD=Standard deviation

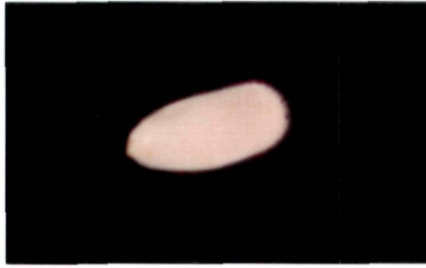


Plate 1: Egg of *L. serricorne*

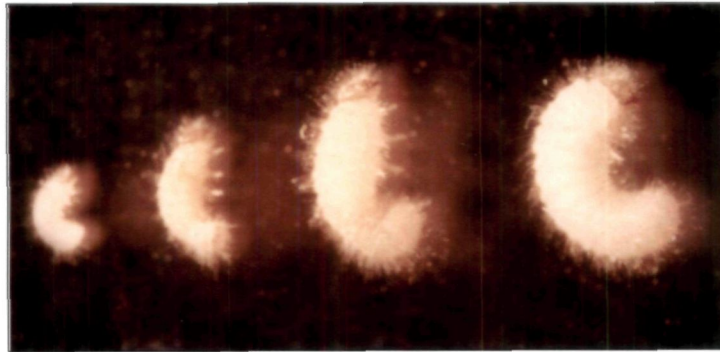


Plate 2: Larval instars of *L. serricorne*

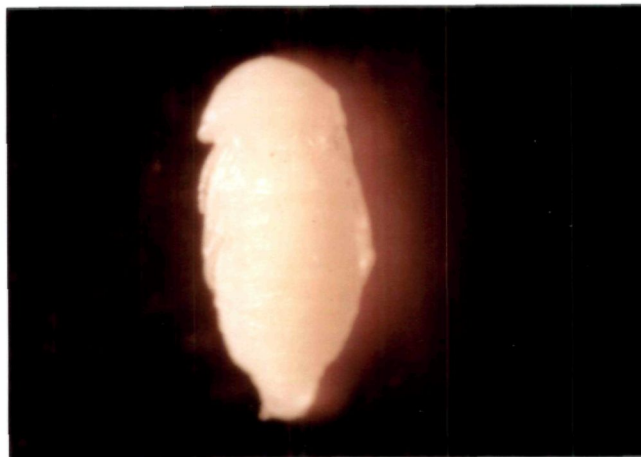


Plate 3: Pupa of *L. serricorne*



Plate 4: Adult male and female of *L. serricorne*

posteriorly. Spiracles two pairs, one on prothorax, second on metathorax and remaining 8 pairs on first eight abdominal segments. First instar lasted for 7-9 days with a mean of 8.00 ± 0.77 days. Larval head capsule width was 0.13 to 0.15 mm with a mean 0.14 ± 0.01 mm and body length was 0.45-0.63 mm with a mean of 0.54 ± 0.07 mm (Table 2 and 3).

Second instar larva

Similar to first instar larva except for the size and body possessing longer setae. The duration of this instar was 8 to 10 days with a mean of 9.00 ± 0.89 days. Larval head capsule width was 0.16 to 0.19 mm (mean 0.17 ± 0.01 mm) and body length was 0.62 to 0.75 mm (mean 0.68 ± 0.05 mm).

Third instar larva

It was similar in respect of physical features to second instar larva, except that it was stouter with body covered sparsely with longer fine setae. Duration of this instar varied from 8 to 11 days with an average of 9.50 ± 1.10 days. The width of head capsule ranged from 0.33 to 0.36 mm (mean 0.34 ± 0.01 mm) and length of the body was 0.78 to 1.30 mm (mean 1.04 ± 0.18 mm).

Fourth instar larva

Comparatively bigger and stouter than any of the larval instars with well developed head capsule. Body was covered with long fine setae. It occupied 9 to 11 days with an average of 10.00 ± 0.93 days. The head capsule width was 0.47 to 0.52 mm (mean 0.49 ± 0.01 mm) and body length 2.04 to 2.62 mm (mean 2.51 ± 0.23 mm).

Inside the shell constructed by the fourth instar larva it became inactive, straight and creamy white at pre pupal stage. Prepupal stage occupied a day.

Table 3. Measurement of different instars of *L. serricorne*

Stages	Head capsule width (mm)		Body length (mm)	
	Range	Average \pm SD	Range	Average
First instar	0.13-0.15	0.14 \pm 0.01	0.45-0.63	0.54 \pm 0.07
Second instar	0.16-0.19	0.17 \pm 0.01	0.62-0.75	0.68 \pm 0.05
Third instar	0.33-0.36	0.34 \pm 0.01	0.78-1.30	1.04 \pm 0.18
Fourth instar	0.47-0.52	0.49 \pm 0.01	2.04-2.62	2.51 \pm 0.23

SD=Standard deviation

Pupa was exarate, uniformly white and devoid of setae. Head is deflexed, not visible dorsally, eyes yellow to brown. Mouth parts and antennae enclosed in a separate membranous area, pronotum large, convex and wide. Wing pads placed obliquely on either side of the mesonotum and extended to tip of 6th abdominal sternum. Three pairs of legs, free and completely visible were placed below the wing pad ventrally. Genital papillae were less prominent in male than in female and diverging in the latter. Pupal period lasted for 6 to 11 days (mean 8.50 ± 1.80 days) (Plate 3).

Adult

Shells constructed by the last instar larvae in turmeric powder after pupation bear holes for emergence of adults. Freshly formed adults were pale brown in colour and they turned dark brown within 4 to 5 days. The adult beetle rested for 3-4 days (mean 3.5 ± 1.00 days) in the pupal chamber before becoming active and emerged out through the exit hole.

Adult beetles were small, reddish brown, head not visible from above, antennae serrate, eyes large and protruding with head capsule rounded. The dorsal surface had short hairs. Five abdominal sterna were visible, legs similar with 5 segmented tarsi. Males were smaller than the female (Plate 4).

Premating period

Soon after emergence, the male ran towards the female and there after made several attempts before copulating successfully. The duration varied from 1 to 2 days (mean 1.5 ± 0.48 days) (Table 4).

Table 4. Oviposition, longevity and fecundity of *L. serricorne*

Sl. No.	Difference stages	Duration	
		Range	Average±SD
1.	Pre-mating period (days)	1-2	1.50±0.48
2.	Mating period (minutes)	10-75	42.50±23.69
3.	Pre-ovipositional period (days)	2-3	2.5±0.50
4.	Ovipositional period (days)	1-6	3.50±1.62
5.	Adult longevity (days)		
	Female	13-18	15.50±1.48
	Male	12-14	13.00±2.79
6.	Fecundity	12-62	37.00±18.42
7.	Per cent hatchability	78-83	80.50±1.27

SD=Standard deviation

Mating period

The newly emerged males were more active than the females. The male chased the female and made number of attempts to hold the female. After holding the female, the male climbed over the back of the female. With the help of claws the male held on the fine setae in the elytra of the female and established union, the male got down and turned to the opposite side. Still in copula the female moved about. Mating period lasted for 10 to 75 min with an average of 42.50 ± 23.69 min. Multiple mating was observed among both the sexes.

Preovipositional period

Preovipositional period ranged from 2-3 days with a mean of mean 2.5 ± 0.50 days.

Ovipositional period

Eggs were laid singly, dispersed on the surface of turmeric powder, on the first day itself. Subsequently the egg laying decreased. Most of the eggs were laid with in four days, sometimes it stretched to six days.

Fecundity

The fecundity ranged from 12.00 to 62.00 eggs with an average of 37.00 ± 18.42 eggs.

Per cent hatchability

The per cent hatchability of eggs varied from 78 to 83 with a mean of 80.05 ± 1.27 .

Adult longevity

Adult female survived for 13-18 days with an average of 15.50 ± 1.48 days whereas male survived for 12-14 days with an average of 13.00 ± 2.79 days.

4.2 HOST PREFERENCE STUDIES OF *L. serricorne*

Results of the investigation on per cent survival, mean developmental period and growth index of *L. serricorne* on different spices viz., coriander, chilli powder, turmeric powder, cumin, fennel, black pepper and ajowan are presented in Table 5.

4.2.1 Per cent survival

Total number of adults emerged from different spices presented in the Table 5 revealed that significantly highest number (51.00) of adult emergence was observed on coriander followed by fennel (40.00), cumin (19.50) and turmeric powder (19.30). However, cumin and turmeric powder were on par with each other. Least number of adult emergence was noticed in black pepper and ajowan (10.00), which was on par with each other.

4.2.2 Mean developmental period (MDP)

Mean developmental period of *L. serricorne* on different spices ranged from 44.22 to 86.92 days. Developmental period was shortest (44.22 days) in coriander which was on par with that of fennel (45.20 days). This was followed by turmeric powder (63.09 days) and cumin (72.25 days). On the other hand, the mean developmental period was significantly longer (86.92 days) in black pepper, which was on par with chilli powder (80.64 days).

4.2.3 Growth index value (GI value)

As evidenced by the growth index values (Table 5), coriander exhibited a value of 0.089 and hence it was the most suitable host for development of *L. serricorne*. The

Table 5. Per cent survival, mean development period (MDP) and growth index (GI) value of *L. serricorne* for different spices

Spices	Per cent survival	MDP (days)	GI value
Coriander	51.00 ^a	44.22 ^d	0.089
Chilli powder	10.40 ^d	80.64 ^a	0.030
Turmeric powder	19.30 ^c	63.09 ^c	0.042
Cumin	19.50 ^c	72.25 ^b	0.041
Fennel	40.00 ^b	45.20 ^d	0.082
Black pepper	10.00 ^d	86.92 ^a	0.026
Ajowan	10.00 ^d	70.84 ^b	0.032

Means followed by same letter donot differ significantly by DMRT (P=0.05)

descending order of suitability was coriander (0.089), fennel (0.082), turmeric powder (0.042), cumin (0.041), ajowan (0.032), chilli powder (0.030) and black pepper (0.026).

4.3 STORAGE LOSSES IN DIFFERENT SPICES BY CIGARETTE BEETLE

The results on population buildup, per cent weight loss and per cent moisture content are presented in Table 6. Damage caused by *L. serricornis* in different spices has been shown in Plate 5.

4.3.1 Population buildup

The results of the multiplication of *L. serricornis* on different spices are presented in Table 6. At 3 months after release, adult population was significantly higher (312.79) in coriander followed by fennel (235.12) and turmeric powder (145.25). Lowest (3.46) population was observed in black pepper followed by chilli powder (46.64) and ajowan (72.94).

At 6 months after release, significantly highest (1756.63) and lowest (3.46) number of beetles were noticed in coriander and black pepper respectively. Further, population buildup trend was similar to that of 3 months after release in other spices except increase in number of beetles.

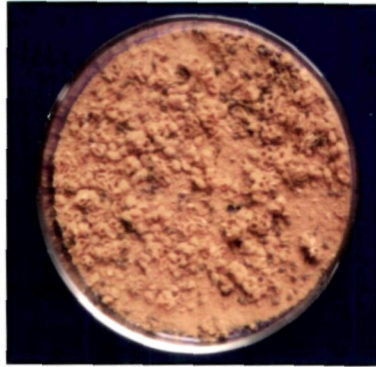
4.3.2 Per cent weight loss

The data on the percentage weight loss due to infestation of cigarette beetle varied significantly. Weight loss increased with increase in storage period. At 3 months after storage, 13.68 per cent (Table 6) weight loss was recorded in coriander which was significantly higher compared to rest of the treatments. This was followed by fennel (9.96%). However, per cent weight loss in turmeric powder (7.15%) and cumin (6.84%)

Table 6. Insect population, weight loss and moisture content in different spices by *L. serricornis* at three and six months after storage

Sl. No.	Treatment	Population build up		Weight loss (%)		Moisture content (%)		
		3 MAR	6 MAR	3 MAR	6 MAR	Initial	3 MAR	6 MAR
1.	Coriander	312.79 ^a	1756.63 ^a	13.68 ^a	35.31 ^a	12.11	12.15	12.30
2.	Chilli powder	26.64 ^f	43.36 ^f	1.67 ^e	4.32 ^f	10.16	10.20	10.21
3.	Turmeric powder	145.25 ^c	443.47 ^c	7.15 ^c	22.75 ^c	13.15	13.92	13.92
4.	Cumin	100.56 ^d	250.63 ^d	6.84 ^c	16.76 ^d	11.84	11.92	11.92
5.	Fennel	235.12 ^b	517.20 ^b	9.96 ^b	27.14 ^b	6.30	7.00	7.00
6.	Black pepper	3.46 ^g	3.46 ^g	0.27 ^f	0.30 ^g	13.19	13.20	13.21
7.	Ajowan	72.94 ^e	149.32 ^e	2.74 ^d	7.50 ^e	7.40	7.41	7.41

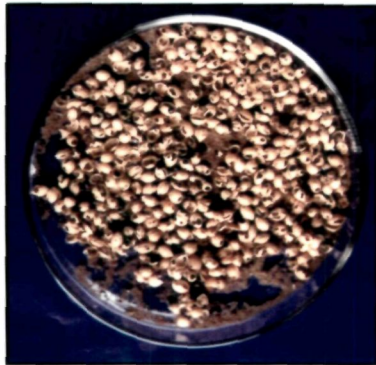
MAR = Months after release
Mean followed by the same letter donot differ significantly by DMRT (P=0.05)



Turmeric powder



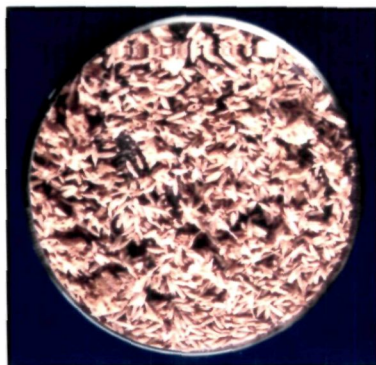
Turmeric rhizome



Coriander



Fennel



Cumin



Chilli powder



Ajowan

Plate 5: Damage caused by *L. serricornis* in different spices

were on par with each other. Significantly least (0.27%) weight loss was observed in black pepper followed by chilli powder (1.67%). Weight loss in ajowan was 2.74 per cent.

After a storage period of 6 months, weight loss among the spices ranged from 0.30 to 35.31 per cent (Table 6). Weight loss was significantly highest (35.31%) in coriander followed by fennel (27.14%) and turmeric powder (22.75%). Per cent weight loss was lowest (0.30%) in black pepper followed by chilli powder (4.32%) and ajowan (7.50%) and in cumin it was 16.76 per cent.

4.3.3 Per cent moisture content

Per cent moisture content of different spices as influenced by the infestation of cigarette beetle are presented in Table 6.

No significant change in the moisture content of the spices was noticed at any of the observation intervals.

4.4 MANAGEMENT OF CIGARETTE BEETLE USING PLANT PRODUCTS AND SAND IN DIFFERENT SPICES

Different plant products and sand was evaluated for their efficacy against cigarette beetle in different spices viz., coriander, fennel, cumin, ajowan and turmeric powder has been presented separately.

4.4.1 Coriander

4.4.1.1 Adult mortality

As seen from the (Table 7) the per cent adult mortality ranged form 4.75 to 100 per cent at five days after release (DAR). Significantly highest mortality (100%) was achieved in sweet flag rhizomé powder at 0.5 per cent followed by lakke leaf powder 5

Table 7. Effect of plant products and sand on survival, population buildup and per cent weight loss by *L. serricornis* on coriander

Sl. No.	Treatments	Dosage % (w/w)	Adult mortality (%)				Population build up			Per cent weight loss		
			5 DAR	10 DAR	15 DAR	60 DAR	90 DAR	120 DAR	60 DAR	90 DAR	120 DAR	
1.	Neem seed kernel powder	2.0	76.12 ^d	89.82 ^b	100.00 ^a	0.00 ^f	4.62 ^g	9.74 ^f	0.00 ^d	0.00 ^g	0.21 ^g	
2.	Sweetflag powder	0.5	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^f	0.00 ^h	0.00 ^g	0.00 ^d	0.00 ^g	0.00 ^h	
3.	Lakke leaf powder	5.0	94.40 ^b	100.00 ^a	100.00 ^a	0.86 ^e	11.56 ^e	16.23 ^e	0.00 ^d	0.21 ^f	0.35 ^f	
4.	Tamarind leaf powder	5.0	69.70 ^e	79.93 ^c	83.40 ^b	3.60 ^d	30.67 ^c	36.95 ^d	0.35 ^c	0.83 ^d	2.71 ^d	
5.	Periwinkle leaf powder	5.0	30.06 ^f	39.96 ^d	100.00 ^a	25.40 ^c	27.09 ^d	111.22 ^b	0.12 ^b	2.50 ^b	6.24 ^b	
6.	Neem leaf powder	5.0	22.72 ^g	34.97 ^e	100.00 ^a	0.94 ^e	9.93 ^f	16.88 ^e	0.00 ^d	0.61 ^e	1.21 ^e	
7.	Custard apple seed powder	5.0	79.89 ^c	100.00 ^a	100.00 ^a	0.00 ^f	0.00 ^h	0.00 ^g	0.00 ^d	0.00 ^g	0.00 ^h	
8.	Sand	30	14.76 ^h	19.73 ^f	80.00 ^c	58.79 ^b	59.34 ^b	106.62 ^c	0.00 ^d	2.40 ^c	4.20 ^c	
9.	Control		4.75 ⁱ	4.91 ^g	61.14 ^d	74.84 ^a	121.82 ^a	142.78 ^a	2.30 ^a	4.60 ^a	7.20 ^a	

DAR = Days after release
Mean followed by the same letter do not differ significantly by DMRT (P=0.05)

per cent (94.40%). Effectiveness of other treatments in descending order was 79.89 per cent in custard apple seed powder at 5 per cent, neem seed kernel powder 2 per cent (76.12%) and 5 per cent tamarind leaf powder (69.70%). 5 per cent periwinkle leaf powder registered 30.06 per cent mortality followed by 5 per cent neem leaf powder (22.72%) and 14.76 per cent mortality in sand (30%). The mortality in all the treatments differed significantly from the untreated control which recorded 4.75 per cent. The cumulative mortality at 10 days after release recorded cent per cent in case of sweet flag, lakke leaf powder and custard apple seed powder followed by neem seed kernel powder. Similar trend was noticed in case of five days after release. At 15 days after release cent per cent mortality was noticed in sweet flag powder, neem seed kernel powder, periwinkle leaf powder and neem leaf powder followed by tamarind leaf powder (83.40%) and sand (80.00%). As the time lapsed the mortality increased but it was significantly low incase of sand as compared to all other treatments.

Sweet flag rhizome powder recorded 100 per cent mortality even at 5 days of release. The survival of the beetles in sand treatments was much higher to indicate their low effectiveness but which differed significantly from the control.

4.4.1.2 Population buildup

Data on the population buildup presented in the Table 7 reveals that 60 days after treatment no adult beetle was seen in treatments of neem seed kernel powder, sweet flag rhizome powder and custard apple seed powder. Significantly high number of adult was noticed in sand (58.79) followed by periwinkle leaf powder. In tamarind leaf powder and lakke leaf powder, number beetles were 3.60 and 0.86 respectively.

At 90 days after storage, no adult beetle (Table 7) could be seen in the treatments viz., sweet flag powder and custard apple seed powder. Among the spice protectants

significantly more number of beetles (59.34) was observed in sand followed by tamarind leaf powder and periwinkle leaf powder. In lakke leaf powder, neem leaf powder and neem seed kernel powder population was 11.56, 9.93 and 4.62 respectively.

At 120 days after treatments, periwinkle leaf powder recorded highest (111.22) population buildup followed by sand (106.62) and tamarind leaf powder (36.95). Sweet flag and custard apple seed powder recorded no population buildup and found to show significant superiority over other treatments. This was followed by neem seed kernel powder (9.74) and neem leaf powder (16.88) which was on par with that of lakke leaf powder (16.23).

4.4.1.3 Per cent weight loss

The growth and development of the grubs on treated coriander reflected on per cent loss caused. The per cent weight loss (Table 7) ranged from 0.00 to 0.35 per cent at 60 days after treatment as against 2.30 per cent in untreated check. Per cent weight loss was zero in the treatments viz., neem seed kernel powder, sweet flag powder, lakke leaf powder, neem leaf powder, custard apple seed powder and sand and were significantly superior to other treatments. The next best treatments were tamarind leaf powder (0.35%) followed by periwinkle leaf powder (0.12%) which differed significantly from the control (2.30%).

At 90 days after treatment no weight loss was obtained in neem seed kernal powder, sweet flag and custard apple seed powder. Lowest weight loss was obtained in periwinkle leaf powder which differed significantly from untreated check. Lakke leaf powder, neem leaf powder, tamarind leaf powder and sand recorded 0.21, 0.61, 0.83 and 2.40 per cent weight loss respectively and they significantly differ from the rest of the treatments.

At 120 days after storage, there was no weight loss in sweet flag powder and custard apple seed powder. This was followed by neem seed kernel powder. Further the effect of other treatments was similar to that at 90 days after storage with a marginal increase in weight loss.

4.4.2 Fennel

4.4.2.1 Adult mortality

The sensitivity of *L. serricornis* to the effect of spice protectants and sand presented in Table 8 reveals the superiority of sweet flag powder which was significantly harmful to beetles at 5 days after release by recording cent per cent mortality followed by lakke leaf powder (91.80%) and custard apple seed powder (87.70). In contrast sand (9.80%), neem leaf powder (15.30%) were significantly less harmful to beetle by recording low percentage of mortality. Other treatments viz., neem seed kernel powder, tamarind leaf powder and periwinkle leaf powder recorded mortality to the extent of 65.00, 34.40, 24.70 per cent respectively and differed significantly from untreated check.

At 10 days after release sweet flag rhizome powder and tamarind leaf powder recorded cent per cent mortality which was on par with custard apple seed powder, which recorded 99.49 per cent mortality. Sand recorded low per cent mortality of 76.10 per cent and which differed significantly from untreated check (5.65%). Neem seed kernel powder recorded 95 per cent mortality which was on par with lakke leaf powder (95.00%). periwinkle leaf powder recorded 25.50 per cent mortality which was on par with the neem leaf powder (26.10) and differed significantly from the control.

The data on the mortality of beetle at 15 days after release showed that the mortality in neem seed kernel powder, sweet flag powder, lakke leaf powder, tamarind leaf powder and custard apple seed powder was cent per cent followed by periwinkle leaf

Table 8. Effect of plant products and sand on survival, population buildup and per cent weight loss by *L. serricornis* on fennel

Sl. No.	Treatments	Dosage % (w/w)	Adult mortality (%)				Population build up			Per cent weight loss		
			5 DAR	10 DAR	15 DAR	60 DAR	90 DAR	120 DAR	60 DAR	90 DAR	120 DAR	
1.	Neem seed kernel powder	2.0	65.00 ^d	95.00 ^b	100.00 ^a	0.00 ^e	0.00 ^f	0.00 ^g	0.00 ^e	0.00 ^g	0.00 ^g	
2.	Sweetflag powder	0.5	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^e	0.00 ^f	0.00 ^g	0.00 ^e	0.00 ^g	0.00 ^g	
3.	Lakke leaf powder	5.0	91.80 ^b	95.00 ^b	100.00 ^a	5.45 ^d	11.40 ^d	49.79 ^d	0.10 ^d	0.22 ^f	0.34 ^f	
4.	Tamarind leaf powder	5.0	34.40 ^e	100.00 ^a	100.00 ^a	12.96 ^c	27.38 ^c	85.00 ^c	0.21 ^c	0.92 ^c	4.00 ^c	
5.	Periwinkle leaf powder	5.0	24.70 ^f	25.50 ^c	90.34 ^b	0.00 ^e	9.93 ^e	17.22 ^e	0.00 ^e	0.65 ^d	2.70 ^d	
6.	Neem leaf powder	5.0	15.30 ^g	26.10 ^c	76.10 ^c	0.00 ^e	0.00 ^f	12.97 ^f	0.00 ^e	0.54 ^e	0.99 ^e	
7.	Custard apple seed powder	5.0	87.70 ^c	99.49 ^a	100.00 ^a	0.00 ^e	0.00 ^f	0.00 ^g	0.00 ^e	0.00 ^g	0.00 ^g	
8.	Sand	30	9.80 ^h	14.52 ^d	76.10 ^c	16.31 ^b	35.62 ^b	101.71 ^b	0.65 ^b	2.40 ^b	6.00 ^b	
9.	Control		5.00 ⁱ	5.65 ^e	10.70 ^d	28.66 ^a	91.66 ^a	131.98 ^a	1.40 ^a	6.30 ^a	8.20 ^a	

DAR = Days after release
Mean followed by the same letter donot differ significantly by DMRT (P=0.05)

powder (90.34%) and sand (76.10%) which was found on par with neem leaf powder (76.10%), where as in control least mortality of 10.70 per cent was recorded.

4.4.2.2 Population buildup

As evidenced from the Table 8 all the treatments were significantly superior to untreated check. No population buildup was noticed in case of neem seed kernel powder, sweet flag powder, periwinkle leaf powder, neem leaf powder and custard apple seed powder and were found superior at 60 DAR followed by lakke leaf powder (5.45) and tamarind leaf powder (12.96). Significantly higher number of (16.31) beetles was recorded in sand which differed significantly from untreated check (28.66%).

Similar pattern of population buildup was noticed in 90 and 120 DAR with similar chronological order with increase in the population buildup as time lapsed. No weight loss was recorded in neem seed kernel powder, sweet flag, custard apple seed powder and were superior treatments which differed significantly from untreated check.

4.4.2.3 Per cent weight loss

Weight loss among the treatments (Table 8) ranged from 0.00 to 1.40 per cent at 60 DAR, 0.00 to 6.30 per cent at 90 DAR and 0.00 to 8.20 per cent at 120 DAR. The efficacy of the treatments in reducing the loss was a reflection of their superiority in suppressing the adult emergence. At 60 DAR neem seed kernel powder, sweet flag powder, periwinkle leaf powder, neem leaf powder and custard apple seed powder were significantly superior over other treatments which recorded no loss followed by lakke leaf powder (0.10%). The highest loss among the treatments recorded was in sand (0.65%) followed of tamarind leaf powder (0.21%) which differ significantly from untreated check (1.40%).

The treatment superiority at 90 DAR registered significantly no loss with neem seed kernel powder, sweet flag powder and custard apple treatments followed by lakke leaf powder (0.22%) and neem leaf powder (0.54%). Sand (2.40%) showed significantly least weight loss followed by tamarind leaf powder (0.92%) and periwinkle (0.65%). Similar pattern of weight loss was noticed at 120 DAR of adult.

4.4.3 Cumin

4.4.3.1 Adult mortality

Observations on the mean per cent adult mortality of *L. serricornis* after 5, 10 and 15 days after release are presented in Table 9.

A perusal of the data revealed that cent per cent mortality was noticed in sweet flag powder and custard apple seed powder at 5 days after release. These were followed by neem seed kernel powder (95.50%) and lakke leaf powder (89.90%). Lowest per cent mortality of 4.99 per cent was observed in control which was on par with that of sand (9.95%). Other treatments viz., tamarind leaf powder, periwinkle leaf powder and neem leaf powder recorded 80.51 per cent, 60.15 per cent and 30.12 per cent mortality.

At 10 DAR except periwinkle leaf powder (85.55%), neem leaf powder (64.85%) and sand (14.85%), all the treatments, recorded cent per cent mortality as against the control (10.13%) it was significantly different from rest of the treatments. Even at 15 DAR also same trend was noticed with increase in the per cent of mortality.

4.4.3.2 Population buildup

Population buildup of *L. serricornis* in cumin at 60 DAR, 90 DAR and 120 DAR are presented in the Table 9. Population buildup was nil at 60 DAR. At 90 DAR highest population buildup was noticed in sand (80.14) followed by lakke leaf powder (18.16),

Table 9. Effect of plant products and sand on survival, population buildup and per cent weight loss by *L. serricornis* on cumin

Sl. No.	Treatments	Dosage % (w/w)	Adult mortality (%)				Population build up			Per cent weight loss		
			5 DAR	10 DAR	15 DAR	60 DAR	90 DAR	120 DAR	60 DAR	90 DAR	120 DAR	
1.	Neem seed kernel powder	2.0	95.50 ^b	100.00 ^a	100.00 ^a	0.00	0.00 ^g	0.00	0.00 ^e	0.15 ^e		
2.	Sweetflag powder	0.5	100.00 ^a	100.00 ^a	100.00 ^a	0.00	0.00 ^g	0.00	0.00 ^e	0.00 ^f		
3.	Lakke leaf powder	5.0	89.90 ^c	100.00 ^a	100.00 ^a	0.00	18.16 ^c	0.00	1.30 ^c	1.70 ^b		
4.	Tamarind leaf powder	5.0	80.51 ^d	100.00 ^a	100.00 ^a	0.00	7.67 ^d	0.00	0.99 ^d	1.30 ^c		
5.	Periwinkle leaf powder	5.0	60.15 ^e	85.55 ^b	99.90 ^b	0.00	1.60 ^f	0.00	0.00 ^e	0.17 ^e		
6.	Neem leaf powder	5.0	30.12 ^f	64.85 ^c	75.30 ^c	0.00	3.95 ^e	0.00	0.00 ^e	0.30 ^d		
7.	Custard apple seed powder	5.0	100.00 ^a	100.00 ^a	100.00 ^a	0.00	0.00 ^g	0.00	0.00 ^e	0.00 ^f		
8.	Sand	30	9.95 ^g	14.85 ^c	19.95 ^d	0.00	80.14 ^d	0.00	4.09 ^b	9.10 ^a		
9.	Control		4.99 ^g	10.13 ^e	18.35 ^e	0.00	105.18 ^a	0.00	6.40 ^a	9.20 ^a		

DAR = Days after release
 Mean followed by the same letter do not differ significantly by DMRT (P=0.05)

tamarind leaf powder (7.67) and neem leaf powder (3.95). No population buildup was noticed in neem seed kernal powder, sweet flag powder and custard apple seed powder followed by periwinkle leaf powder (1.60%). Same trend was followed with respect to population build up even at 120 days of release. With no population build up in neem seed kernal powder, sweet flag powder and custard apple seed powder. Sand recorded significantly high population of 90.70. Other treatments viz., *Vinca rosea*, neem leaf powder, tamarind leaf powder and lakke leaf powder recorded 2.39, 5.26, 20.57 and 44.26 population, respectively.

4.4.3.3 Per cent weight loss

Per cent weight loss at 60 DAR, 90 DAR and 120 DAR are represented in table 9. No weight loss was recorded in all the treatments at 60 DAR. At 90 DAR zero per cent weight loss was recorded in all the treatments except lakke leaf powder (1.30%), tamarind leaf treatment (0.99%) and sand (4.09%) which were significantly different from untreated check (6.40%). At 120 DAR no weight loss was recorded in sweet flag and custard apple seed powder followed by neem seed kernal powder (0.15%) which was on par with periwinkle leaf powder (0.17%). Sand recorded high percentage of weight loss (9.10%) which was on par with control (9.20%).

4.4.4 Ajowan

4.4.4.1 Adult mortality

As noted from the table 10 the data on the mortality of adults showed a range between 5.33 to 100 per cent. Highest mortality (100%) was achieved by sweet flag powder followed by custard apple seed powder (95.30%). Sand was found to be significantly inferior by recording 14.40 per cent mortality. The effectiveness of other treatments in the descending trend was neem seed kernal powder (89.71%), lakke leaf

Table 10. Effect of plant products and sand on survival, population buildup and per cent weight loss by *L. serricornis* on Ajowan

Sl. No.	Treatments	Dosage % (w/w)	Adult mortality (%)				Population build up			Per cent weight loss		
			5 DAR	10 DAR	15 DAR	60 DAR	90 DAR	120 DAR	60 DAR	90 DAR	120 DAR	
1.	Neem seed kernel powder	2.0	89.71 ^c	100.00 ^a	100.00 ^a	0.00	0.00 ^g	0.00 ^e	0.00	0.00 ^f	0.00 ^f	
2.	Sweetflag powder	0.5	100.00 ^a	100.00 ^a	100.00 ^a	0.00	0.00 ^g	0.00 ^e	0.00	0.00 ^f	0.00 ^f	
3.	Lakke leaf powder	5.0	85.30 ^d	97.70 ^b	100.00 ^a	0.00	26.33 ^c	43.19 ^b	0.00	1.20 ^c	3.30 ^c	
4.	Tamarind leaf powder	5.0	46.10 ^e	90.35 ^c	100.00 ^a	0.00	10.85 ^d	19.93 ^c	0.00	0.93 ^d	1.30 ^d	
5.	Periwinkle leaf powder	5.0	34.90 ^f	80.70 ^d	100.00 ^a	0.00	5.90 ^e	10.99 ^d	0.00	0.09 ^e	0.94 ^e	
6.	Neem leaf powder	5.0	25.10 ^g	60.05 ^e	90.20 ^b	0.00	1.99 ^f	9.23 ^d	0.00	0.00 ^f	0.00 ^f	
7.	Custard apple seed powder	5.0	95.30 ^b	100.00 ^a	100.00 ^a	0.00	25.00 ^c	42.66 ^b	0.00	1.20 ^c	3.40 ^e	
8.	Sand	30	14.40 ^h	39.31 ^f	49.70 ^c	0.00	32.21 ^b	83.22 ^a	0.00	2.20 ^b	4.10 ^b	
9.	Control		5.33 ⁱ	9.90 ^g	35.27 ^d	0.00	69.55 ^a	85.24 ^a	0.00	3.30 ^a	5.32 ^a	

DAR = Days after release
 Mean followed by the same letter do not differ significantly by DMRT (P=0.05)

powder (85.30%), tamarind leaf powder (46.10%), periwinkle leaf powder (34.90%) and neem leaf powder (25.10%) while to untreated check recorded 5.33 per cent mortality at 5 DAR.

The cumulative mortality at 10 DAR recorded cent per cent mortality in neem seed kernal powder and custard apple seed powder followed by lakke leaf powder (97.70%). With other treatments viz., tamarind leaf powder, periwinkle leaf powder, neem leaf powder and sand the mortality recorded was 90.35 per cent, 80.70 per cent, 60.05 per cent and 39.31 per cent respectively. The mortality data at 15 DAR revealed that all the treatments recorded cent per cent mortality except neem leaf powder (90.20%) and sand (49.70%) which was found significantly inferior to control (35.25%).

4.4.4.2 Population buildup

Data on the population buildup of *L. serricornis* are presented in Table 10 reveals that the plant products and sand significantly reduced the population buildup on treated ajowan seeds. At 60 DAR no population buildup was noticed in any of the treatments and the results were non-significant. At 90 DAR no adult could be seen in treatments of neem seed kernal powder and sweet flag rhizome powder. Among the spice protectants significantly maximum (32.21) beetles was observed in sand followed by lakke leaf powder (26.33) which was found to be on par with custard apple seed powder (25.00). Tamarind leaf powder, *Vinea rosea* leaf powder and neem leaf powder recorded 10.85, 5.90 and 1.99 respectively and differed significantly from untreated check.

At 120 DAR significantly higher number of adults were recorded in sand (83.22) which was on par with the control (85.24). Further effect of other treatments was similar to that at 90 DAR with a increase in the population buildup.

4.4.4.3 Per cent weight loss

The per cent loss in ajwon due to *L. serricornis* is presented in Table 10. The weight loss was nil in all the treatments at 60 DAR. At 90 DAR zero per cent weight loss was recorded in neem seed kernel powder, sweet flat rhizome powder and custard apple seed powder followed by *Vinea rosea* leaf powder (0.09%) and tamarind leaf powder (0.93%). Per cent weight loss was significantly high in sand (2.20%) followed by neem leaf powder (1.20%) which was on par with lakke leaf powder by recording 1.20 per cent mortality. Similar trend was noticed at 120 DAR with slightly high weight loss as that of 90 DAR.

4.4.5 Turmeric

4.4.5.1 Adult mortality

The adult mortality due to plant products and sand ranged from 4.70 and 100.00 per cent at 5 DAR. Sweet flag rhizome powder was found to be slightly effective and caused cent per cent mortality followed by custard apple seed powder (95.30%) and differed significantly from all other treatments. The minimum mortality of 15.20 per cent was found in sand followed by neem leaf powder (19.90%). Other treatments viz., tamarind leaf powder, neem seed kernel powder, lakke leaf powder and periwinkle leaf powder recorded 83.40 per cent, 75.00 per cent, 68.80 per cent and 53.32 per cent mortality respectively which differed significantly from untreated check (4.70%).

The most effective treatment of sweet flag rhizome powder and custard apple seed powder caused cent per cent mortality at 10 DAR and differed significantly over other treatments. Next effective treatment was tamarind leaf powder (95.31%) which was on par with that of neem seed kernel powder (95.00%) followed by lakke leaf powder (85.00%). Least per cent mortality was recorded in neem leaf powder (39.45%) followed

by sand (50.60%) which differed significantly from control. Per cent mortality in periwinkle leaf powder was 69.50 per cent but control recorded only 26.01 per cent mortality.

Even after 15 DAR neem seed kernal powder and sweet flag rhizome powder recorded cent per cent mortality. A moderate mortality of 50.50 per cent was recorded in control. Rest of the treatment results were similar as that of 10 DAR.

4.4.5.2 Population buildup

Table 11 indicated that there was no population buildup of *L. serricorne* in turmeric rhizome at 60 DAR. But at 90 DAR population ranged from 0.00 to 150.79. Zero population buildup was recorded in neem seed kernal powder, sweet flag rhizome powder and custard apple powder. periwinkle leaf recorded highest population buildup of 19.30 which was significantly inferior over other treatments. Next inferior treatment was sand (13.26) followed by tamarind leaf powder (11.26) which was on par with the neem leaf powder (9.74). Lakke leaf powder recorded 5.70 population which was significantly different from that of control. Even after 120 DAR no population buildup was noticed in neem seed kernal powder, sweet flag rhizome powder and custard apple seed powder followed by neem leaf powder (9.11) which was on par with that of lakke leaf powder (12.38). Maximum population buildup was noticed in periwinkle leaf powder (34.30) followed by tamarind leaf powder (28.12) and sand (24.80) which differed significantly from other treatments.

4.4.5.3 Per cent weight loss

Data obtained on the per cent weight loss (Table 11) shows that no weight was recorded at 60 DAR and all the treatments were non-significant. After 90 days of release no weight was found in neem seed kernal powder, sweet flag rhizome powder and custard apple seed powder followed by lakke leaf powder (0.10%) and sand (0.77%).

Table 11. Effect of plant products and sand on survival, population buildup and per cent weight loss by *L. serricornis* on turmeric rhizome

Sl. No.	Treatments	Dosage % (w/w)	Adult mortality (%)			Population build up			Per cent weight loss		
			5 DAR	10 DAR	15 DAR	60 DAR	90 DAR	120 DAR	60 DAR	90 DAR	120 DAR
1.	Neem seed kernel powder	2.0	75.00 ^d	95.00 ^b	100.00 ^a	0.00	0.00 ^f	0.00 ^f	0.00	0.00 ^f	0.00 ^g
2.	Sweetflag powder	0.5	100.00 ^a	100.00 ^a	100.00 ^a	0.00	0.00 ^f	0.00 ^f	0.00	0.00 ^f	0.00 ^g
3.	Lakke leaf powder	5.0	68.80 ^e	85.00 ^c	100.00 ^a	0.00	5.70 ^e	12.38 ^e	0.00	0.10 ^e	0.99 ^e
4.	Tamarind leaf powder	5.0	83.40 ^c	95.31 ^b	97.30 ^b	0.00	11.26 ^d	28.12 ^c	0.00	0.20 ^c	2.50 ^c
5.	Periwinkle leaf powder	5.0	53.32 ^f	69.50 ^d	95.12 ^c	0.00	19.30 ^b	34.33 ^b	0.00	1.40 ^b	3.40 ^b
6.	Neem leaf powder	5.0	19.90 ^g	39.45 ^f	85.90 ^d	0.00	9.74 ^d	9.11 ^e	0.00	0.23 ^{de}	0.39 ^f
7.	Custard apple seed powder	5.0	95.30 ^b	100.00 ^a	100.00 ^a	0.00	0.00 ^f	0.00 ^f	0.00	0.00 ^f	0.00 ^g
8.	Sand	30	15.20 ^h	50.60 ^e	59.50 ^e	0.00	13.26 ^c	24.80 ^d	0.00	0.77 ^d	1.35 ^c
9.	Control		4.70 ⁱ	26.01 ^g	50.50 ^f	0.00	150.79 ^a	154.00 ^a	0.00	6.90 ^a	8.20 ^a

DAR = Days after release

Mean followed by the same letter do not differ significantly by DMRT (P=0.05)

Periwinkle leaf powder recorded 0.23 per cent weight loss which was on par with lakke leaf powder and sand which differed significantly from the control. At 120 DAR also no per cent weight loss was recorded in neem seed kernal powder, sweet flag leaf powder and custard apple seed powder followed by neem leaf powder (0.39%) and lakke leaf powder (0.99%). Maximum weight loss was in periwinkle leaf powder (3.40%) followed by tamarind leaf powder (2.50%). Neem leaf powder and sand recorded 3.40 per cent and 1.35 per cent weight loss as against control (8.20%).

4.5 LETHAL EFFECT OF LOW TEMPERATURE ON CIGARETTE BEETLE

4.5.1 Larva

4.5.1.1 Effect of exposure time on mortality of cigarette beetle

Per cent mortality of *L. serricornis* differed significantly between 4 h and 15 days (Table 12). Overall highest per cent mortality of 81.81 per cent was noticed in 15 days exposure irrespective of temperature followed by 8 days exposure (56.80%), 6 days (51.79%), 4 days (35.20%) and 2 days (31.10%). Four h treatment recorded least per cent mortality of 29.10 per cent.

4.5.1.2 Effect of temperature on mortality of cigarette beetle

The highest mortality (100%) over control was achieved by -18°C exposure followed by -4°C (99.18%) and rest of the temperature treatments offered less protection to turmeric irrespective of time period of exposure.

4.5.1.3 Interaction effect between exposure time and temperature on mortality of cigarette beetle

Interaction studies of both time and temperature revealed that the highest per cent larval mortality of 100 per cent was observed in -18°C for 4 h, -4°C for 4 days, 0°C for 15

Table 12. Lethal effect of temperature on larvae of cigarette beetle

Exposed period	Per cent mortality at different temperatures °C						Mean
	4	0	-4	-18	Control (room temperature)		
4 h	0.00 ^l	0.00 ^l	89.90 ^c	100.00 ^a	0.00 ^l		29.10 ^f
2 days	0.00 ^l	0.00 ^l	95.20 ^b	100.00 ^a	0.00 ^l		31.10 ^e
4 days	0.00 ^l	0.00 ^l	100.00 ^a	100.00 ^a	0.00 ^l		35.20 ^d
6 days	22.80 ^h	20.30 ^g	100.00 ^a	100.00 ^a	0.00 ^l		51.79 ^c
8 days	25.89 ^f	30.00 ^e	100.00 ^a	100.00 ^a	0.00 ^l		56.80 ^b
15 days	100.00 ^a	100.00 ^d	100.00 ^a	100.00 ^a	0.00 ^l		81.81 ^a
Mean	16.80^d	18.30^c	99.18^b	100.00^a	0.00^f		47.80

Mean followed by the same letter donot differ significantly by DMRT (P=0.05)

days and 4°C for 15 days, followed by -4°C for 2 days (95.20%). Among the different temperature time interaction -18°C for 4 h was effective as the least period of exposure (4 h) helps in suppressing *L. serricornis* larval population.

4.5.2 Pupa

4.5.2.1 Effect of exposure time on mortality of cigarette beetle

The effect of period of exposure irrespective of temperature (Table 13) revealed that, among all exposure periods, significantly highest per cent pupal mortality of 81.93 per cent was noticed in 15 day exposure followed by 8 days (70.40%) and 6 days (64.70%) other treatments viz., 4 days and 2 days recorded 60.55 per cent and 55.01 per cent mortality respectively. Four hour exposure period recorded least mortality of 44.93 per cent.

4.5.2.2 Effect of temperature on mortality of cigarette beetle

Temperature effect on per cent pupal mortality irrespective of period of exposure recorded least per cent mortality at 4°C exposure which differed significantly from all other treatments. Highest mortality (cent per cent) was recorded in -18°C and -4°C whereas room temperature recorded no mortality.

4.5.2.3 Interaction effect between exposure time and temperature on mortality of cigarette beetle

Highest per cent mortality (100%) was observed at -4°C and -18°C for 4 h exposure and 0°C for 15 days exposure as against the control which recorded zero per cent mortality at all the periods of exposure.

Table 13. Lethal effect of low temperature on pupa of cigarette beetle

Exposed period	Per cent mortality at different temperatures °C						Control (room temperature)	Mean
	4	0	-4	-18				
4 h	0.00 ^k	19.69 ^j	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	44.93 ^f	
2 days	14.75 ^k	34.80 ^h	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	55.01 ^e	
4 days	32.20 ^l	41.62 ^e	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	60.55 ^d	
6 days	39.95 ^g	54.81 ^d	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	64.70 ^c	
8 days	40.30 ^f	81.62 ^b	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	70.40 ^b	
15 days	64.73 ^c	100.00 ^a	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	81.93 ^a	
Mean	27.60^c	60.36^b	100.00^a	100.00^a	100.00^a	0.00^l	63.20	

Mean followed by the same letter donot differ significantly by DMRT (P=0.05)

4.5.3.1 Effect of exposure time on mortality of cigarette beetle

Per cent mortality of cigarette beetle adult differed significantly between 4 h to 15 days. Overall highest per cent mortality of 84.51 per cent was noticed (Table 14) in 15 days exposure irrespective of temperature followed by 8 days (83.21%) and 6 days (81.40%). Other treatments viz., 4 and 2 days recorded 55.00 and 45.25 per cent mortality respectively. Four hour exposure recorded significantly low mortality of only 22.40 per cent.

4.5.3.2 Effect of temperature on mortality of cigarette beetle

Effect of temperature in enhancing mortality of cigarette beetle adult irrespective of time, revealed that -18°C temperature was the best treatment which caused 100 per cent mortality followed by -4°C (91.22%). Other treatments viz., 4°C and 0°C recorded 41.61 and 72.82 per cent mortality respectively, which differed significantly from untreated check (0.00%).

4.5.3.3 Interaction effect between exposure time and temperature on mortality of cigarette beetle

Interaction effect of time and temperature showed that -18°C for 4 h exposure was found to be better by recording 100 per cent mortality and was on par with -4°C for 6 days and 0°C for 6 days. Control recorded no mortality for all the time period exposure.

Table 14. Lethal effect of low temperature on adults of cigarette beetle

Exposed period	Per cent mortality at different temperatures °C						Mean
	4	0	-4	-18	Control (room temperature)		
4 h	0.00 ^l	0.00 ^l	60.05 ^g	100.00 ^a	0.00 ^l	22.40 ^f	
2 days	19.70 ^k	40.00 ^j	75.09 ^d	100.00 ^a	0.00 ^l	45.25 ^e	
4 days	41.90 ^j	57.35 ^h	81.11 ^b	100.00 ^a	0.00 ^l	55.50 ^d	
6 days	61.30 ^f	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	81.40 ^c	
8 days	71.80 ^e	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	83.21 ^b	
15 days	79.90 ^c	100.00 ^a	100.00 ^a	100.00 ^a	0.00 ^l	84.51 ^a	
Mean	41.61^d	72.82^c	91.22^b	100.00^a	0.00^l	63.50	

Mean followed by the same letter do not differ significantly by DMRT (P=0.05)

Discussion

V. DISCUSSION

Studies on the biology of cigarette beetle under laboratory conditions, host preference, its storage losses in different spices, evaluation of plant products, sand and lethal effect of low temperature on cigarette beetle were carried out and findings of the investigation, are discussed hereunder.

5.1 BIOLOGY OF CIGARETTE BEETLE ON TURMERIC POWDER

The present study revealed a mean incubation period of 8.00 ± 0.74 days on turmeric powder. The present findings are in agreement with Howe (1957), Sivik *et al.* (1957), Kismali and Goktay (1998) and Allotey and Unanaowo (1994). The observations of shape of egg and colour are in accordance with Frank *et al.* (1957). Retief and Nicholas (1988) and Narasimha Rao (2003).

The present investigations revealed four instars, each occupying 8.00 ± 0.77 , 9.00 ± 0.89 , 9.50 ± 1.10 and 10.00 ± 0.93 days respectively with total larval period occupying an average of 36.50 ± 3.32 days. These results are not in agreement with Howe (1957) who reported 43 to 68 days at 22.5°C and 50 per cent RH on wheat. The possible reason for variation in duration could be attributed to the difference in the host and prevailing environmental factors.

The pupal period was found to be varying from 6 to 11 days with an average of 8.50 ± 1.80 days. These observations are comparable with studies of Samuel *et al.* (1984). However, present findings are not in agreement with Runner (1919) and De Bussy (1917) who reported pupal period to be 5 days and Jones (1913) who reported it to be 4 days.

The adult longevity in the present study is in conformity with the findings of Farag and Ismail (1985), Howe (1957) and Allotey and Unanaowo (1994).

Pre-oviposition period of 2 to 3 days was recorded with an average of 1.5 ± 0.48 days are in accordance with Bare *et al.* (1947). Whereas 6 to 8 days was reported by Dick (1937), 1-3 days was reported by Stamatini (1935) and 2 days according to Canazalli (1935), 2-5 days reported to by Jones (1913), 2-6 days according to Runner (1919).

With regards to the oviposition period, the findings of the present study are in close agreement with Dick (1937), Howe (1957) and Jones (1913) disproving the contents of present findings. Runner (1919) recorded ovipositional period of 21 days and according to Stamatini (1935) it was 4 to 14 days.

The mean fecundity recorded (37.00 ± 18.42) in the present study agrees with the observation of Vanderveen (1940), Runner (1919) and Allotey and Unanaowo (1994).

The ratio of female to male (1:1) observed in the present study is in close agreement with the findings of Howe (1957), Sivik *et al.* (1957), Blalodia and Chari (1976) and Narasimha Rao *et al.* (2003).

5.2 HOST PREFERENCE STUDIES OF CIGARETTE BEETLE

For the development of *L. serricornis*, coriander provided highest per cent survival (51.00%) followed by fennel (40.00%), cumin (19.50%) and turmeric powder (19.30%) which were on par with each other. However, least number of adult emergence was noticed in chilli powder (10.40%), black pepper (10.00%) and ajowan (10.00%). Based on the per cent survival coriander was the most preferred host followed by fennel. Next preferred hosts were cumin and turmeric powder. Chilli powder, black pepper and ajowan were among the least preferred host.

Based on the mean developmental period, fennel was most preferred as it recorded shorter mean developmental period of 45.20 days and was on par with

coriander (44.22 days). Next preferred host was turmeric powder (63.09 days) followed by cumin (72.25 days) and ajowan (70.84 days). Black pepper and chilli powder were least preferred recording high mean developmental period (MDP) of 86.92 and 80.64 days, respectively.

Using per cent survival and mean developmental period, growth index was calculated. On the basis of higher growth index value hosts are ranked (Jha and Yadav, 1994). Coriander recorded higher growth index value of 0.089 and was most preferred host followed by fennel (0.082). Turmeric powder was the next preferred host as it recorded GI value of 0.042 followed by cumin (0.041), ajowan (0.032) and chilli powder (0.030). Black pepper recorded least GI value of 0.026 indicating least suitability.

The results of the present findings deviated from the findings of Jha and Yadav (1994) who reported the suitability in descending order as fennel, chilli, coriander, cumin and black pepper. Change in the host preference behaviour of the insect may be due to prevailing environmental conditions like temperature, relative humidity, *etc.*

5.3 STORAGE LOSSES IN DIFFERENT SPICES BY CIGARETTE BEETLE

At 3 months of storage adult population was significantly high in the coriander (312.72) followed by fennel (235.12). Lower population was in black pepper (3.46) followed by chilli (26.64), ajowan (72.94). Cumin and fennel which recorded 100.56 and 235.12 adults respectively. At 6 months after storage, insect population buildup showed similar trend to that of 3 months storage period. With respect to weight loss at 3 and 6 months after storage coriander recorded 13.68 and 35.31 per cent respectively followed by fennel (9.96 and 27.14%), turmeric powder (7.15 and 22.75%), cumin (6.84 and 16.76%) and ajowan (2.74 and 7.50%). Black pepper recorded least weight loss (0.27 and 0.30%) followed by chilli powder (1.67 and 4.32%), which differed significantly from

the control. Initial moisture content of different spices viz., coriander, chilli, turmeric, cumin, fennel, black pepper and ajowan were 12.11 per cent, 10.16 per cent, 13.15 per cent, 11.84 per cent, 6.30 per cent, 13.19 per cent and 7.40 per cent, respectively. At 6 months of storage same spices recorded 12.30, 10.21, 13.92, 11.92, 7.00, 13.21 and 7.41 per cent respectively, indicating a very slight difference.

Population buildup and weight loss were also in parallel with growth index value and showed the host preference of cigarette beetle.

Agarwal *et al.* (1981) however, found average insect population to be 292 and total weight loss to be 8.85 per cent after 7 months of storage in the turmeric rhizome. The present study indicated average insect population to be 443.47 and per cent with a weight loss of 22.75 per cent after 6 months of storage. Variation could be due to the form of turmeric used and also prevailing environmental conditions like RH, temperature *etc.*

5.4 MANAGEMENT OF CIGARETTE BEETLE USING PLANT PRODUCTS AND SAND

Awareness of hazards posed by synthetic pesticides including resistance development has necessiated the need for naturally occurring protectants. During the present investigation certain plant products and sand have been evaluated for their efficacy against *L. serricorne*. The results of the investigations are discussed hereunder.

5.4.1 Coriander

5.4.1.1 Sweet flag rhizome powder

Among the plant products, sweet flag powder was found to be highly effective against *L. serricorne* in coriander at 0.5 per cent caused cent per cent mortality of adults at 5 days after release of beetles and hence no adult emergence, and no weight loss was

recorded even at 120 days after storage (Fig. 1 and 2). These findings are in agreement with Siva Srinivasu (2001) who reported 100 per cent mortality of *S. oryzae* and *R. domenicana* in sorghum grains treated with 0.5 per cent sweet flag powder and the present findings are also in confirmity with Shivanna (1988), Kittur (1990), and Yevoor (2003) on various insects in different grains. Perhaps may be due to strong ovicidal and larvicidal action, neither the embryo transformed to larva nor the larva could develop into adult and hence no damage and loss in weight.

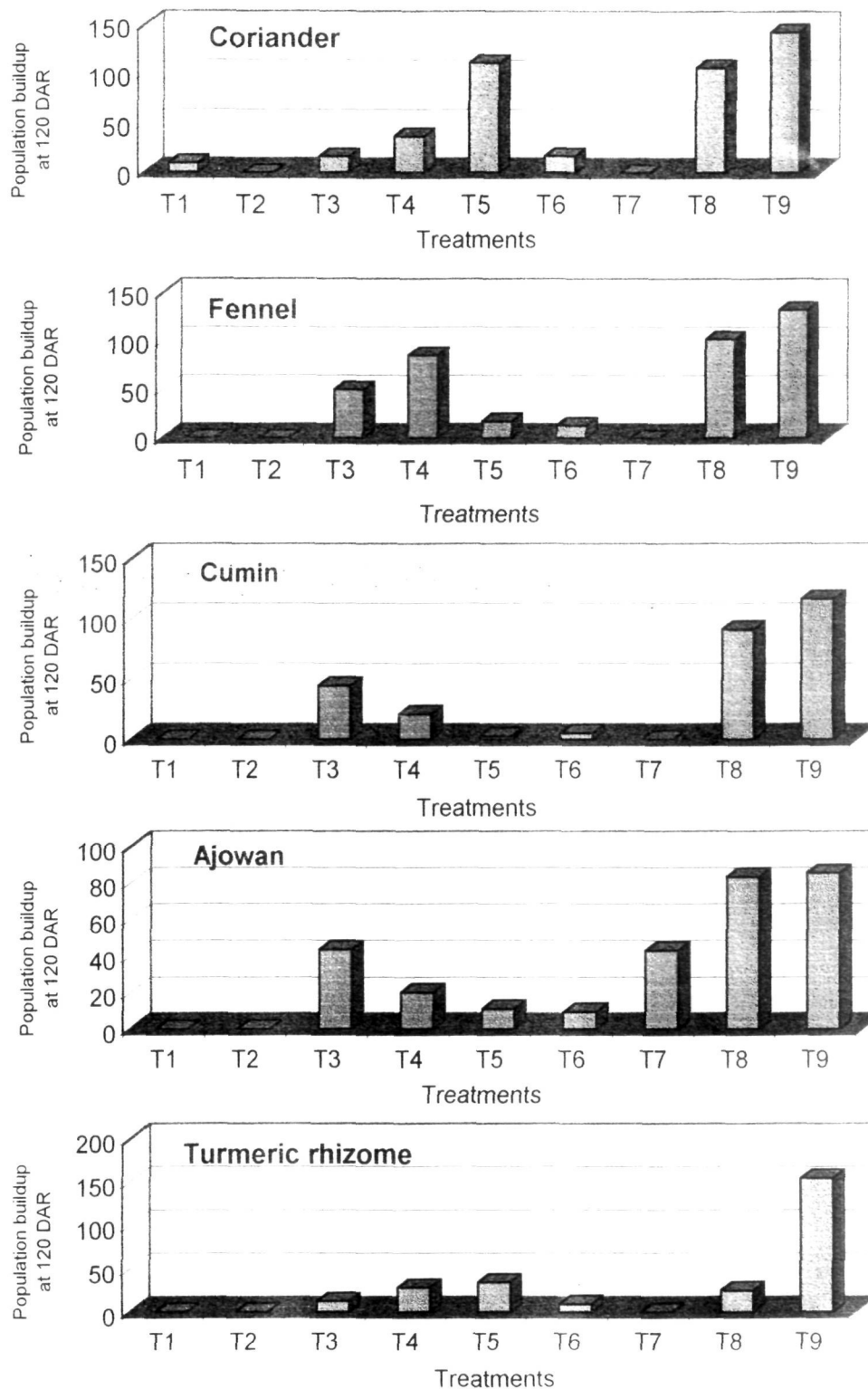
5.4.1.2 Neem seed kernal powder

Neem seed kernal powder @ 2 per cent was effective in suppressing the cigarette beetle which recorded adult mortality of 72.12 per cent at 5 days after release as against control (4.75%). It recorded 89.82 per cent mortality at 10 DAR which was significantly higher than other treatments except sweet flag and lakke leaf powder at 10 DAR. Radhakrishnan *et al.* (1983), Sowumni and Akinnusi (1983) reported similar findings. Yevoor (2003) recorded cent per cent mortality in *S. oryzae* on maize.

The population build up of *L. serricornis* at 60, 90 and 120 DAR varied from 0.00 to 9.74 adults which was significantly less than the control. Since the product hindered the adult emergence, the per cent weight loss was also significantly less as compared to control (Fig. 2). Findings of Shivanna (1988) are in agreement with present study, while findings of Yevoor (2003) against *S. oryzae* contradicted the findings. Deviation could be attributed to the change of host and insect species.

5.4.1.3 Lakke leaf powder

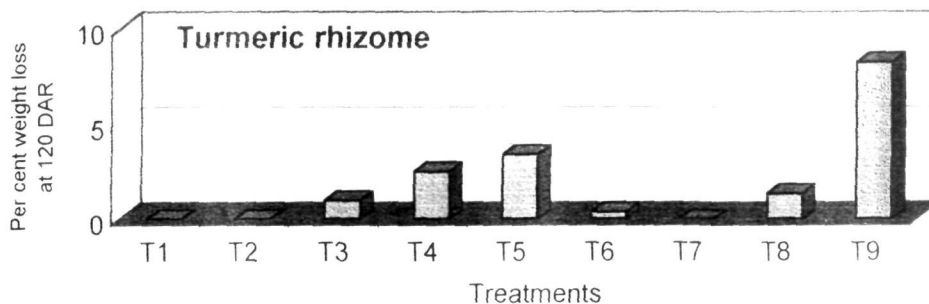
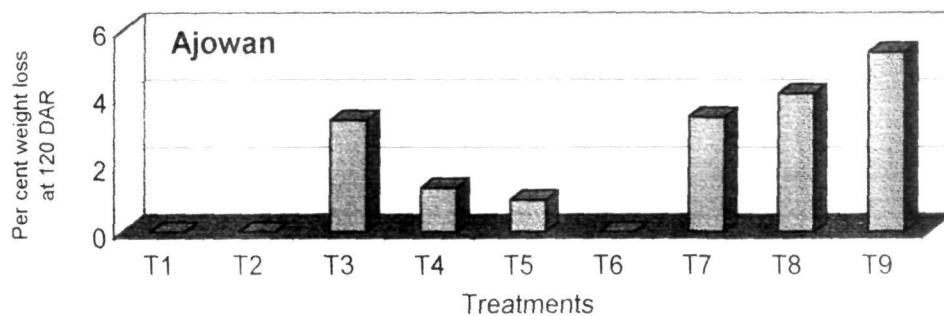
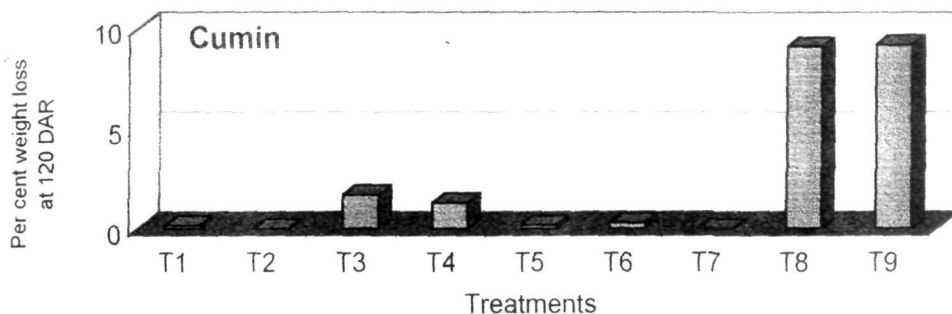
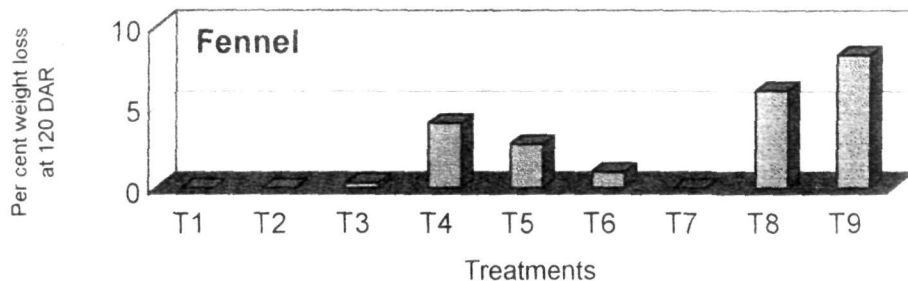
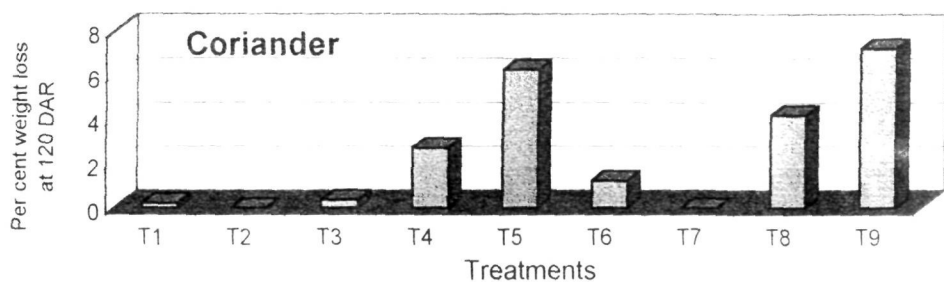
Coriander treated with 5.00 per cent lakke leaf powder recorded 94.40 per cent cumulative adult mortality at 5 DAR and cent per cent mortality at 10 DAR, indicating its effectiveness. At 120 DAR 16.23 adult beetles were observed and 0.35 per cent was the



LEGEND

T1 - Neem seed kernel powder, T2 - Sweetflag powder, T3 - Lakke leaf powder, T4 - Tamarind leaf powder, T5 - Periwinkle leaf powder, T6 - Neem leaf powder, T7 - Custard apple seed powder, T8 - Sand, T9 - Control

Fig. 1. Effect of plant products and sand on population buildup of *L. serricorne* at 120 DAR



LEGEND

T1 - Neem seed kernel powder, T2 - Sweetflag powder, T3 - Lakke leaf powder, T4 - Tamarind leaf powder, T5 - Periwinkle leaf powder, T6 - Neem leaf powder, T7 - Custard apple seed powder, T8 - Sand, T9 - Control

Fig. 2. Effect of plant products and sand on per cent weight loss by *L. serricorne* at 120 DAR

weight loss (Fig. 1 and 2). These findings are in agreement with Mishra *et al.* (1992) but contradict with Yevoor (2003).

5.4.1.4 Tamarind leaf powder

Tamarind leaf powder at 5 per cent was proved to be ineffective in suppressing the beetle population. Adult mortality ranged from 69.70 to 83.40 per cent at 5 and 15 DAR. Population buildup ranged from 3.60 to 36.95 at 60 and 120 DAR and weight loss ranged from 0.35 to 2.71 at 60 and 120 DAR. These results significantly different compared to other treatments. These results are not in agreement with Ambadkar and Khan (1994) who reported that tamarind leaf was having repellent action against *L. serricorne*.

5.4.1.5 Periwinkle leaf powder

Periwinkle leaf powder is also ineffective as it did not cause more than 50 per cent mortality of adults at 5 DAR. The adult mortality ranged from 30.06 to 100 per cent at 5 and 15 DAR. The treatments may failed to cause ovicidal or larvicidal action and hence permitted a population build up of 111.22 at 120 DAR and increased per cent weight loss of 6.24 per cent at 120 DAR, which differed significantly form other treatments. Plant product failed to prove a repellent action as reported by Ambadkar and Khan (1994).

5.4.1.6 Neem leaf powder

Neem leaf powder at 5 per cent did not induce more than 50 per cent mortality at 5 DAR. Population buildup at 60, 90 and 120 DAR ranged from 0.94 to 16.88 and were significantly different from untreated check. This tend was evident even in per cent weight loss. Neem has got insect growth regulating and insecticidal property and effectively control the population buildup there by reducing per cent grain weight loss as reported by Pandey and Singh (1997) which disproves the present findings.

5.4.1.7 Custard apple seed powder

Cent per cent mortality of cigarette beetle was recorded in custard apple (5%) treated coriander at 10 DAR. Further, no adult emergence and weight loss was recorded at the end of 120 DAR (Fig. 1 and 2) which differed significantly from untreated control. At 10 DAR custard apple seed powder was on par with sweet flag and lakke leaf powder which also recorded cent per cent mortality. Present findings are in agreement with Siva Srinivasu (2001) and Yevoor (2003).

5.4.1.8 Sand

Sand at 30 per cent admixture was found to be less effective compared to other treatments of plant products. The mortality ranged from 14.76 to 80.00 per cent at 5 to 15 DAR and population buildup ranged from 58.79 to 106.62 at 60 to 120 DAR. Weight loss was recorded to be 4.20 per cent at 120 DAR. The mortality could be possibly due to mechanical injury caused to beetle during movement as reported by Kittur (1990) who reported that sand at 30 per cent caused only 20 per cent mortality of *C. chinensis*. In another study sand at 3 cm top layer treatment also was in effective in causing mortality of *T. castaneum* and *C. pusillus* as reported by Kalasagond (1998).

5.4.2 Fennel

5.4.2.1 Sweet flag rhizome powder

Sweet flag rhizome powder at 0.5 per cent afforded maximum protection against *L. serricornis* in fennel. The adult mortality was cent per cent at 5 DAR as against no mortality in the control. The treatment completely prevented the population build up at 120 DAR and no weight loss was recorded (Fig. 1 and 2). These findings are in accordance with Pandey *et al.* (1976), Jilani (1984) and Shivanna (1988) on various stored grain pests.

5.4.2.2 Neem seed kernal powder

Neem seed kernal powder at 2 per cent recorded cent per cent mortality at 15 DAR. At the end of 120 days no population buildup and weight loss was noticed. The data highlighted the significant effect of neem seed kernal compared to other treatments. Control recorded least mortality of 5.00 per cent at 5 DAR and population buildup to the extent of 131.98 at 120 DAR. Per cent weight loss also was high (8.20%). Similar findings were recorded by Siva Srinivasu (2001). This could be attributed to the antifeedant property of the neem seed kernal.

5.4.2.3 Lakke leaf powder

Lakke leaf powder at 5 per cent was found to be less effective eventhough it caused 91.80 per cent mortality at 5 DAR. Due to failure in causing good early adult mortality, leading to ovipositiion and adult emergence. Therefore at 120 DAR, 49.79 adults emerged and 0.34 per cent weight loss was caused. To support the present finding Mishra *et al.* (1992) reported that lakke leaf powder @ 5.00 per cent caused 73.00 per cent mortality of *S. oryzae* on wheat seeds at 30 DAR.

5.4.2.4 Tamarind leaf powder

Though all treatments were significantly superior over control. Tamarind leaf powder at 5 per cent proved to be ineffective as it caused less than 50 per cent mortality at 5 DAR and caused population buildup of 85 at 120 DAR and a significant weight loss as high as 4.00 per cent at 120 DAR compared to other treatments. These findings are not in agreement with Ambadkar and Khan (1994) who reported that tamarind leaf is having repellent action against cigarette beetle.

5.4.2.5 Periwinkle leaf powder

During the present study, periwinkle leaf powder at 5 per cent was found to be moderately effective as it was slow acting. It recorded only 24.70 per cent mortality at 5 DAR, 25.50

and 90.30 per cent mortality at 10 and 15 DAR. Due to failure in causing sufficient adult mortality at 120 DAR, 17.22 beetle population and 2.70 per cent weight loss was recorded. These results contradict the findings of Ambadkar and Khan (1994).

5.4.2.6 Neem leaf powder

Data on the adult mortality, population buildup and per cent weight loss due to infestation of cigarette beetle in fennel varied significantly. Neem leaf powder could not afford more than 80 per cent mortality even at 15 DAR compared to other treatments, eventhough population buildup and weight loss were comparatively low at 120 DAR (12.97 and 0.99%). The per cent mortality at 15 DAR was 76.10 per cent. These findings are in confirmity with Pandey and Singh (1997).

5.4.2.7 Custard apple seed powder

Custard apple seed powder at 5 per cent recorded maximum protection against cigarette beetle in fennel. The adult mortality was cent per cent at 15 DAR, eventhough only 87.70 per cent mortality was found at 5 DAR. It shows its slow acting property in fennel. In course of time, no population build up and weight loss was seen at any of the intervals. The present study confirms the findings of Yevoor (2003).

5.4.2.8 Sand

Sand at 30 per cent admixture was ineffective compared to all other treatments and it recorded significantly low mortality of 76.10 per cent at 15 DAR and high population buildup (101.71) and high per cent weight loss (6.00%) at 120 DAR (Fig. 1 and 2). On the other hand, significantly least of 10.70 per cent adult mortality was noticed in control at 15 DAR. These finding are in agreement with Kalasagond (1998).

5.4.3 Cumin

5.4.3.1 Sweet flag rhizome powder

Among the plant products, sweet flag rhizome powder was found to be highly effective against cigarette beetle at 0.5 per cent causing cent per cent adult mortality at 5 days after release of adult beetles. Further, no adult population and weight loss was noticed at the end of 120 days of storage (Fig. 1 and 2). This may be due to the fumigant activity of sweet flag rhizome powder. This finding concur with Siva Srinivasu (2001), Yevoor (2003) and Kim *et al.* (2003).

5.4.3.2 Neem seed kernal powder

Neem seed kernal powder @ 5 per cent was also highly effective as it caused cent per cent mortality at 5 DAR. No population build up and no weight loss was observed throughout the experimental period. This treatment was significantly superior over control. These finding are in agreement with Yevoor (2003) who reported cent per cent mortality of *S. oryzae* in maize. However, findings of Kalasgond (1998) were not in accordance with present findings which could be due to the difference in the host and insect species. Shivanna (1988), Jilani (1984), Krishna Prasad (1977), Mathur *et al.* (1998) and Kittur (1990) also contradicted present findings.

5.4.3.3 Lakke leaf powder

Eventhough the product at 5 per cent induced cent per cent mortality at 10 DAR, high population buildup of 44.26 and high weight loss of 1.70 per cent was noticed at 120 DAR which differed significantly from other treatments. The treatment might have failed to induce larvicidal and ovicidal effect and hence permitted a population buildup in cumin. The chemical constituents of cumin could be responsible for this effect. The present findings agree with the studies of Yevoor (2003).

5.4.3.4 Tamarind leaf powder

Tamarind leaf powder was moderately effective as it recorded 80.51 per cent mortality at 5 DAR which differed significantly from the control (4.99%). Population buildup and weight loss were 20.57 and 1.30 per cent, respectively, indicating its moderate effectiveness. This might be due to repellent action against cigarette beetle in cumin which supports findings of Ambadkar and Khan (1994).

5.4.3.5 Periwinkle leaf powder

Eventhough Periwinkle at 5 per cent did not record cent per cent mortality at 15 DAR, comparatively low population buildup of 2.39 and weigh loss of 0.17 per cent was noticed at 4 months after release. It proved its effectiveness next to sweet flag rhizome powder, custard apple seed powder and neem seed kernal powder. These findings are in agreement with Ambadkar and Khan (1994).

5.4.3.6 Neem leaf powder

Neem leaf powder at 5 per cent showed moderate effectiveness in suppressing the populations of cigarette beetle compared to other treatments which differed significantly from the control. Adult mortality ranged from 30.12 to 75.20 per cent at 5 and 15 DAR, respectively. Adult emergence was upto 5.26 and caused weight loss upto 0.30 per cent. These findings are supported by Pandey and Singh (1997). However, Juneja and Patel (1994) strongly contradicted the present findings.

5.4.3.7 Custard apple seed powder

Best treatment among all the treatments was custard apple seed powder at 5 per cent. It recorded cent per cent mortality, no population buildup and no weight loss throughout the experimental period. This treatment was on par with sweet flag rhizome

powder. Control recorded least mortality of 4.99 per cent at 5 DAR and high population buildup and weight loss of 116.14 and 9.20 per cent respectively.

5.4.3.8 Sand

Sand 30 per cent admixture was the least effective treatment, as it recorded least mortality of 19.95 per cent at 15 DAR. Population buildup of 90.70 and weight loss of 9.10 per cent was recorded which was on par with the control. The findings are in agreement with Kalasgond (1998) and Kittur (1990).

5.4.4 Ajowan

5.4.4.1 Sweet flag rhizome powder

Sweet flag rhizome powder at 0.5 per cent proved to be highly promising in controlling the beetle population. The product induced 100 per cent mortality at 5, 10 and 15 DAR. The population buildup and weight loss caused by cigarette beetle was also nil, indicating its superiority. These findings are in agreement with Siva Srinivasu (2001) who also reported 100 per cent mortality of *S. oryzae* and *R. domenic*a in stored sorghum treated with 0.5 per cent sweet flag powder and also in confirmity with Shivanna (1988), Kittur (1990) and Yevoor (2003) on various insects in different stored grains. The effect of sweet flag may be due to the fumigant activity as reported by Kim *et al.* (2003) against cigarette beetle.

5.4.4.2 Neem seed kernal powder

Neem seed kernal powder at 2 per cent caused the mortality of adult beetle ranging from 89.71 to 100 per cent at 5 and 10 DAR. The treatment retained the effect even up to 120 DAR by preventing the population buildup and weight loss (Fig. 1 and 2). The present study is in confirmity with Yevoor (2003) who reported that the effect may be

due to insect growth regulating and insecticidal property. Findings of Shivanna (1988) contradicted present findings.

5.4.4.3 Lakke leaf powder

This product is not effective eventhough it recorded 85.30 per cent mortality at 5 DAR. Adult emergence on the treated ajowan was significantly high (43.19) at 120 DAR. The weight loss ranged from zero to 3.30 per cent at 60 and 120 DAR. Due to failure in causing early high mortality there might be egg laying in the ajowan which could lead to adult emergence. These findings are in agreement with the findings of Yevoor (2003).

5.4.4.4 Tamarind leaf powder

Tamarind leaf powder at 5 per cent was moderately effective as it recorded only 46.10 per cent adult mortality at 5 DAR. Population build up ranged from zero to 19.93 and weight loss increased upto 1.30 per cent at 120 DAR as against the control. Control recorded 85.24 adult and 5.32 per cent weight loss at 120 DAR. It differed significantly from other treatments. This effect might be due to slight repellent action of tamarind leaf powder as reported by Ambadkar and Khan (1994).

5.4.4.5 Periwinkle leaf powder

Periwinkle leaf powder at 5 per cent was significantly superior compared to tamarind leaf powder, eventhough initial mortality was low. Adult mortality ranged from 34.90 to 100 per cent at 5 and 15 DAR. Population buildup ranged from zero to 10.99 and weight loss ranged from zero to 0.94 per cent as against the control. Moderate effectiveness of Periwinkle might be due to the effect of the host. These findings are in agreement with Ambadkar and Khan (1994) who reported repellent activity of Periwinkle against *L. serricorne*.

5.4.4.6 Neem leaf powder

Neem leaf powder at 5 per cent was found to be effective eventhough mortality ranged from 25.10 to 90.20 per cent at 5 and 15 DAR. Population buildup went upto 9.23 and there was no weight loss at 120 DAR. This might be due to ovicidal and larvicidal action which are in accordance with Pandey and Singh (1997).

5.4.4.7 Custard apple seed powder

Custard apple seed powder failed to cause cent per cent mortality at 5 DAR as it is slow acting. At 10 DAR it caused 95.30 per cent mortality. Population build up to the extent of 42.66 was noticed and there was 3.40 per cent weight loss at 120 DAR. This treatment was next best treatment to neem seed kernal powder and sweet flag powder. Compared to other spices, in ajowan it did not induce good effectiveness. Present findings however, do not concur with Siva Srinivasu (2001) and Yevoor (2003) who reported cent per cent mortality, no weight loss and population build up in different grains with different insect species.

5.4.4.8 Sand

Sand at 30 per cent admixture was found to be least effective compared to all other treatments of plant products against *L. serricornis* in ajowan. Adult mortality ranged from 14.40 to 49.70 at 5 and 15 DAR. Population buildup went upto 83.22 which was on par with the control. The weight loss also increased to 4.10 per cent which significantly differed from all other treatments. Findings of Kittur (1990) and Kalasagond (1998) are in good agreement with the current findings.

5.4.5 Turmeric

5.4.5.1 Sweet flag rhizome powder

Sweet flag rhizome powder ranked first in preventing infestation in turmeric rhizome from cigarette beetle causing cent per cent mortality at 5 DAR. As such no adult

emergence and no weight loss was noticed even at 120 DAR (Fig. 1 and 2). The findings of Siva Srinivasu (2001), Yadav (1971), Shivanna (1988), Kittur (1990) and Yevoor (2003) are in support of above results who recorded significantly higher repellent, ovipositional, deterrent and ovicidal effect of sweet flag rhizome powder against different insects. Kim *et al.* (2003) recorded fumigant activity of sweet flag against cigarette beetle.

5.4.5.2 Neem seed kernal powder

Neem seed kernal powder at 2 per cent inflicted 75.00 to 100 per cent mortality of cigarette beetle at 5 and 10 DAR as against only 4.70 to 5.50 per cent mortality in untreated check. There was no population buildup and no weight loss throughout the experimental period. This may be due to antifeedant, repellent and ovicidal action of neem seed kernal powder. These results are in confirmity with Radhakrishnan *et al.* (1983), Sowumni and Akinnusi (1983) and Yevoor (2003).

5.4.5.3 Lakke leaf powder

Lakke leaf powder at 5 per cent was effective by recording 68.80 to 100 per cent mortality at 5 and 15 DAR. Population build up ranged from zero to 1.23 and weight loss ranged from zero to 0.99 per cent at 60 and 120 DAR. These finding are in agreement with Mishra *et al.* (1992) but are contradicted by Yevoor (2003).

5.4.5.4 Tamarind leaf powder

Tamarind leaf powder at 5 per cent was proved to be ineffective as it recorded 83.40 per cent mortality at 5 DAR compared to control. Population buildup went upto 28.12 and weight loss upto 2.50 per cent at 120 DAR. These findings contradicted the findings of Ambadkar and Khan (1994) who reported that tamarind leaf powder was having highly repellent action against *L. serricorne*.

5.4.5.5 Periwinkle leaf powder

This product also proved its ineffectiveness as it recorded 53.32 to 95.12 per cent mortality at 5 and 15 DAR. Population buildup went up to 34.30 and weight loss upto 3.40 per cent at 120 DAR. Failure to cause ovicidal and larvicidal effects might be the reason for its ineffectiveness.

5.4.5.6 Neem leaf powder

Neem leaf powder at 5 per cent was moderately effective by causing 19.90 to 85.90 per cent mortality at 5 and 10 DAR. Population build up ranged from zero to 9.11 and weight loss ranged from zero to 0.39 per cent at 60 and 120 DAR. These findings are not in accordance with Pandey and Singh (1997).

5.4.5.7 Custard apple seed powder

It is found to be more effective at 5 per cent than lakke leaf powder, neem leaf powder, tamarind leaf powder and Periwinkle leaf powder as it recorded cent per cent mortality at 10 DAR. No population buildup and no weight loss was recorded at 30, 60 and 120 DAR of adults. The study confirms the findings of Shivanna (1988) and Yevoor (2003).

5.4.5.8 Sand

Sand at 30 per cent admixture was found to be least effective in controlling cigarette beetle as it caused low mortality but high population buildup and weight loss. The results are in agreement with findings of Kalasagond (1998).

Plant protectants and sand were tested for persistent toxicity to *L. serricornis* in coriander, fennel, cumin, ajowan and turmeric. Adult mortality was recorded at 5, 10 and 15 DAR. Population buildup and weight loss was recorded at 2, 3 and 4 months after release of beetles.

Among the different treatments, sweet flag powder @ 0.5 per cent was found to be most effective protectant upto 4 months after treatment resulting in 100 per cent mortality at 5 DAR in all the spices. Custard apple seed powder at 5.00 per cent was found to be effective with 100 per cent mortality at 10 DAR in all the species. No weight loss and population buildup was noticed except in ajowan at 120 days after release. Population buildup upto the extent of 42.60 and weight loss to the extent of 3.40 per cent was noticed in ajowan. Neem seed kernal powder 2 per cent also was equally effective by recording cent per cent mortality at 15 DAR in all the spices. Population buildup to the extent of 9.74 and weight loss of 0.21 per cent was noticed in coriander at 120 days of storage. Also 0.15 per cent weight loss was recorded in cumin at 120 DAR. In fennel, ajowan and turmeric powder neem seed kernal was equally effective to sweet flag rhizome powder. Five per cent lakke leaf powder was found to be of moderate to low effectiveness in different species. Tamarind leaf powder and periwinkle leaf powder also were low to moderate in effectiveness. Neem leaf powder also showed its less effectiveness in different species. Sand is least effective among all treatments in all the spices tested.

Taking into account various parameters, sweet flag powder was found most effective spice protectant followed by custard apple seed powder and neem seed kernal powder. Sand was least effective treatment. Lakke leaf powder, tamarind leaf powder, Periwinkle leaf powder and neem leaf powder showed varied of responses in different spices and none of there were good enough.

5.5 LETHAL EFFECT OF LOW TEMPERATURE ON CIGARETTE BEETLE

5.5.1 Larva

Per cent mortality of *L. serricornis* differed significantly between 4 h and 15 days. Highest per cent mortality of 81.81 per cent was recorded in 15 days exposure period

followed by 8 days irrespective of temperature, 100 per cent mortality of larva was noticed at -18°C irrespective of time period of exposure followed by -4°C (99.18%). Interaction studies of both time and temperature revealed range of mortality was zero to cent per cent in different treatments. -18°C for 4 h exposure killed all the larvae. The present findings are in agreement with Howe (1957) who reported that produce stored below -18°C could be safe from attack by *L. serricornis*. Further, present study reveals that -4°C for 4 day is equally effective. These findings are in accordance with Keuchenius (1917) who reported that -5 to 0°C for 5 day exposure, killed all larvae, pupae and adult *L. serricornis* 0°C for 13 days killed all the larvae, according to Swingle (1938) which supports the present findings.

5.5.2 Pupa

Effect of period of exposure irrespective of temperature revealed that, among all exposure periods, significantly highest mortality of 81.93 per cent was noticed in 15 day exposure period followed by (70.40%). Per cent mortality of cent per cent was recorded in -4°C and -18°C temperature irrespective of time period. Interaction effect of temperature and time indicated highest pupal mortality of cent per cent in -4°C for and -18°C for 4 h. These results are contradicted by the findings of Tenhet and Bare (1951) who reported that all the stages of *L. serricornis* were killed at -4°C within 7 days. The present study revealed that 0°C for 15 day kills all the pupae. These findings in agreement with the findings of Swingle (1938) who reported that 0°C for 14 h exposure killed all the pupae.

Further it was also observed that 81.62 per cent mortality of pupa was noticed at 0°C for 8 days exposure followed by 4°C for 15 days (64.73%). Least mortality of zero per cent was recorded in control.

5.5.3 Adult

Irrespective of temperature effect, 84.51 per cent mortality was recorded at 15 days exposure followed by 8 day (83.21%). Irrespective of time effect cent per cent

mortality of adult *L. serricornis* was noticed at -18°C followed by -4°C (91.22%) as against other treatments. Control recorded zero per cent mortality. Zero to cent per cent mortality was recorded in time and temperature interaction effect. -18°C for 4 h recorded 100 per cent mortality. These results agree with Howe (1957). -4°C for 6 days treatment also recorded cent per cent mortality of adults. These results are also supported by Tenhet and Bare (1951). Further, the present study also indicates that 0°C for 8 day causes 100 per cent mortality. These results are contradicted by the findings of Swingle (1938).

FUTURE LINE OF WORK

1. Evaluation of consumer acceptability of the treated material
2. Large scale evaluation of plant products like sweet flag, neem seed kernel powder and custard apple seed powder for protection of spices against *L. serricornis* and popularization of this technique for storage
3. Large scale evaluation of storing spices, tobacco and its industrial products in cold storage to protect from this pest

Summary

VI. SUMMARY

Investigations on cigarette beetle, *Lasioderma serricorne* Fab. with respect to biology, host preference, storage loss studies, management of cigarette beetle using plant products, sand and lethal effect of low temperature carried out under laboratory conditions at the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad during 2003-04 are summarised in this chapter.

Life history of *L. serricorne* was studied on turmeric powder under laboratory conditions. The incubation period occupied 7 to 9 days with an average of 8 days. There were three molts and four instars. The first, second, third and fourth instars completed development with an average of 8.00, 9.00, 9.50 and 10.00 days, respectively. Total larval period lasted for 32 to 41 days with an average of 36.50 days. The full grown larva pupated inside the shell constructed by fourth instar larva and pupal period lasted for 6 to 11 days with an average of 8.50 days. Total life cycle from egg to adult was completed in 57 to 79 days with an average of 68.0 days, beetles freely copulated under laboratory condition, commenced mating at 1 to 2 days after emergence and mating of beetles lasted for 10 to 75 minutes with an average of 42.50 minutes. The pre oviposition period varied from 2 to 3 days with mean of 2.50 days. Oviposition period ranged from 1 to 6 days with an average of 3.50 days. Longevity of adult male was 12 to 14 days with an average of 13.00 days. Similarly female longevity ranged from 13 to 18 days with an average of 15.50 days.

Host preference studies of cigarette beetle under laboratory conditions revealed that per cent survival was maximum (51.00%) on coriander followed by fennel (40.00%), cumin (19.50%) and turmeric powder (14.30%). Significantly least number of adults were noticed in black pepper and ajowan and were found on par with each other.

Developmental period was fastest (44.22 days) on coriander which did not differ significantly from fennel (45.20 days) followed by turmeric powder (63.09 days). While chilli powder and black pepper took comparatively longer period to become adult.

As evidenced by the growth index value, coriander exhibited a value of 0.089 was a most suitable host for its development. The descending order of suitability was coriander (0.089), fennel (0.082), turmeric powder (0.042), cumin (0.041), ajowan (0.032), chilli powder (0.030) and black pepper (0.026).

Population build up was maximum in coriander at 3 months (312.79) followed by fennel (235.12) and turmeric powder (145.25). Lowest population was observed in black pepper (3.47). At 6 months after storage, significantly highest (1756.63) and lowest (3.46) number of beetles was noticed in coriander and black pepper respectively. Further population build up trend was similar to that of 3 months after release except for the increase in number of beetles.

Regarding weight loss, maximum of 13.68 per cent weight loss was seen in coriander, on the contrary, significantly least weight loss (0.27%) was observed in black pepper followed by chilli powder (1.67%) at 3 months after storage. At 6 months after storage, weight loss among the spices ranged from 0.27 to 35.31 per cent which was highest in coriander (35.31%) and lowest in black pepper (0.27%).

Among the different protectants, sweet flag powder (0.5%), neem seed kernel powder (2%), custard apple seed powder (5%) caused cent per cent mortality of adult beetles at 15 days after release in all the spices tested viz., coriander, fennel, cumin, ajowan and turmeric rhizome.

Population build up was not at all observed in sweet flag powder throughout the experimental period. Neem seed kernel powder and custard apple powder were also

proved its effectiveness in all the spices except in coriander and ajowan respectively. Regarding per cent weight loss, treatments viz., sweet flag rhizome powder, neem seed kernel powder and custard apple seed powder were effective in all the spices.

With respect to lethal effect of low temperature -18°C for 4 h, -4°C for 4 days and 0°C for 15 days recorded cent per cent mortality of larvae, pupae and adults.

For the management of *L. serricorne* in spices at -18°C for 4 h is very effective for commercial scale. In small scale and household, protection of spices against *L. serricorne* can be done by keeping them in refrigerator for 15 days.

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BIO-ECOLOGY AND MANAGEMENT OF CIGARETTE BEETLE *Lasioderma serricorne* Fab. (ANOBIIDAE : COLEOPTERA) ON STORED SPICES

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ABSTRACT

Investigations on cigarette beetle, *Lasioderma serricorne* Fab. with respect to biology, host preference, storage losses, management using plant products, sand and lethal effect of low temperature were carried out at University of Agricultural Sciences, Dharwad during 2003-04.

Biology of *L. serricorne* was studied on turmeric powder under laboratory conditions. The incubation period was 7 to 9 days with an average of 8 days. There were three molts and four instars. Total larval period lasted for 32 to 41 days with an average of 36.50 days. Pupal period occupied 6 to 11 days. Longevity of adult male was 12 to 14 day and female was 13 to 18 days.

The host preference studies of *L. serricorne* indicated that coriander was most preferred host followed by fennel, turmeric powder, cumin, ajowan, chilli powder and black pepper was least preferred.

Population buildup and weight loss were maximum in coriander followed by fennel and turmeric powder and lowest in black pepper at three and six months after storage.

Efficacy of spice protectants viz., neem seed kernel powder (2%), sweet flag rhizome powder (0.5%), lakke leaf powder (5.0%), tamarind powder (5.0%), periwinkle leaf powder (5.0%), neem leaf powder (5.0%), custard apple seed powder (5.0%) and sand (30%) against *L. serricorne* in different species were evaluated under laboratory condition. Population buildup and weight loss was not at all observed in sweet flag rhizome powder upto 120 days after release. Neem seed kernel powder and custard apple seed powder were also proved its effectiveness in all the spices except in coriander and ajowan respectively.

Cent per cent mortality of larval, pupal and adult stages of the cigarette beetle was recorded with -18°C for 4 h and with 0°C for 15 days.