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Research Article

A semi-automatic device for mass production of the rice moth, *Corcyra cephalonica* (Stainton) (Lep., Pyralidae), and evaluation of several biological and economic parameters to develop a package of practice for its commercial production

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ABSTRACT: A specially designed larval rearing unit with automatic moth collection device and an oviposition cage that leads to automatic egg collection have been developed, illustrated and described for mass-production of the rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera, Pyralidae). These resulted in solving some of the major problems associated with *Corcyra* production such as moth collection, scale contamination, health hazard, cross infestation, undesirable parasitization, etc. and savings of over 70% on labour. A UV chamber for irradiation of the eggs and a method for cleaning the eggs have also been described. Qualitative and quantitative evaluation of various food grains revealed that coarsely crushed bajra (pearl millet) was the most economical and effective diet over groundnut, sorghum, rice and wheat. Studies were also carried out to assess various biological parameters such as proper ratio of eggs to diet for optimum development and moth emergence; influence of diet when offered in a single dose and split doses on larval development; impact of adult feeding; impact of number of moths per cage on egg-laying; and overall reproductive biology of *C. cephalonica* from egg to adult emergence. The results revealed that over-crowding the larvae or moths in rearing containers had negative impact on production and that feeding the moths had no advantage. Based on various biological and economic parameters, a package of practices for a daily production of 25 to 100 CC eggs of *Corcyra* is provided along with the non-recurring and recurring resources required. A floor plan for an insectary for mass-production of *Corcyra* is also indicated.

KEY WORDS: Rice moth, *Corcyra cephalonica,* semi-automatic production device, biological parameters, commercial production, insectary

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INTRODUCTION

The success of biological control, more particularly through releases of natural enemies by inundation, largely depends on our ability to mass-produce the required biological control agents for timely releases. Mass production of parasitoids and predators calls for an elaborate arrangement to culture their host insects in the laboratory. In cases where the original host of the concerned biological control agent is either not amenable to mass-production or its production is rather tedious and costly, a suitable alternative host will have to be employed. The rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera, Pyralidae), has gained tremendous importance in this regard.

Eggs, larvae and pupae of *C. cephalonica* have been found to serve as perfect factitious hosts for mass-production of about 75 natural enemies – 60 parasitoids, 15 predators – including a few that are highly host-specific in nature. These belong to 17 families in 5 insect orders (Hymenoptera, Heteroptera, Neuroptera, Coleoptera and Diptera) and also served as a host for nematodes and mites. One of the outstanding examples of mass-production of a biocontrol agent, using *C. cephanolica* as a laboratory host, is that of the egg-parasitoid, *Trichogramma* spp. (Hymenoptera, Trichogrammatidae), which are extensively used in the control of sugarcane borers, cotton bollworms, etc. in several countries including India. Thus, *C. cephalonica*, though a serious pest of stored grains under natural conditions, has been found to be an extremely useful insect in altogether a different context! Its wide acceptability as a laboratory host is unique and undoubtedly a boon to entomologists engaged in mass-production of biological control agents (Manjunath, 1993).

Attempts to mass-produce *C. cephalonica* have been made in several laboratories using different natural food

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media like sorghum (sorghum), *Sorghum vulgare*; pearl millet (bajra), *Pennisetum typhoides*; rice, *Oryza sativa*; maize, *Zea mays*; groundnut, *Arachis hypogaea;* finger millet (ragi), *Eleusine coracana***;** etc., but the results have not been uniform with regard to the production and economics (Kamel *et al.,* 1977; Sharma *et al.,* 1978; Medina and Cadapan, 1982). Similarly, different types and sizes of rearing containers, generally made of small wooden or metal boxes or glass jars, have been used. These are filled with known quantity of grains mixed with *C. cephalonica* eggs, closed and arranged in racks until the moths emerged. Lid of such containers was partially lifted and moths collected manually or a with a suction device (Parshad, 1975; Manjunath, 1988, 1993; Jalali and Singh, 1989). Such system is labour intensive and costly and, moreover, the scales that escape from thousands of moths contaminate the laboratory (dirtying the atmosphere, body, cloths) and cause serious health hazard (breathing problem, eye irritation, etc.). Wearing face-mask is recommended, but its prolonged use is very uncomfortable. Further, *Bracon hebetor* Say (Hymenoptera, Braconidae), a larval parasitoid of *C. cephalonica,* was often found to invade the rearing rooms and bring about almost complete control of *C. cephalonica* when its production was expected to reach its peak , thereby upsetting the entire production plans – a case of biological control taking place at the wrong place at a wrong time! The incidence of the mite, *Pyemotes ventricosus* Newport (Acarina, Pyemotidae), a larval parasite of *C. cephalonica,* which can build up large population and cause itching sensation in workers, is another problem. Besides, other stored grain pest like *Tribolium casteneum* Herbst. (Coleoptera, Tenebrionidae) has been often found to enter the rearing rooms, compete with *C. cephalonica* and contaminate the cultures. Heat treatment of the grains at 110° C prior to use has been recommended, but it does not ensure protection against subsequent intrusion by these organisms. Therefore, there was a pressing need to overcome these challenges, especially in view of the tremendous importance of *C. cephalonica* in the production of biological control agents. The semi-automatic production device developed and described in this paper and the recommendation of a package of practices for its commercial production based on the evaluation of various biological and commercial parameters are an attempt to revolutionize the mass-production of *C. cephalonica*.

MATERIALS AND METHODS

A specially designed larval rearing unit with automatic moth collection device and an oviposition cage with automatic egg collection device have been developed as described below. Evaluations of diet preference, reproductive biology and certain economic parameters have been carried out and a package of practices recommended for mass production of *C. cephalonica*.

1. *Corcyra* larval rearing units with automatic moth collection device.

This unit has the following components (Figs. 1 & 1a): Larval rearing trays, Connecting rods, Trolley with a large funnel, Metal frame, Moth collector and Polythene bag.

Fig. 1.

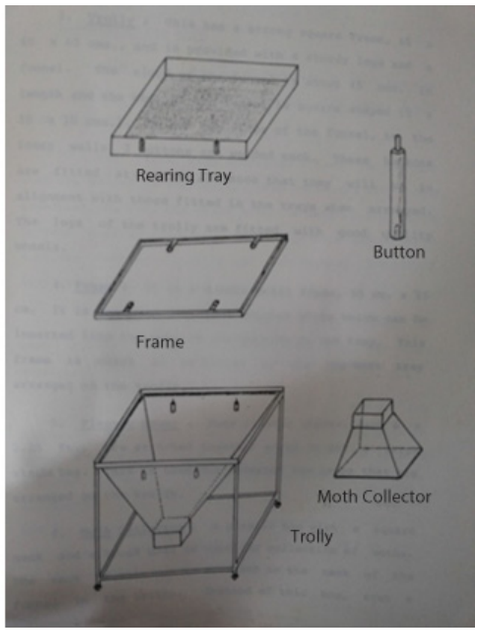


Fig. 1a.

Fig. 1. Corcyra larval rearing unit with automatic moth collection device

Larval rearing trays

These are square trays, 45 x 45 x 6.5 cm, made of GI (galvanize iron) sheet and painted. Two specially designed 'connecting rods' are welded to each of the two opposite sides, 5.0 cm away from each end. Thus, each tray carries 4 connecting rods.

Connecting rods

Each is a solid metal piece, 1.0 cm dia. and 4.5 cm in length. The bottom end has a groove, 1.0 cm long, and the other end is in the form of a narrow neck, 1.0 cm long. The neck of one connecting rod can be inserted into the groove of the other piece. While 4 connecting rods are welded to each tray, 4 loose ones can be used to connect one another so that the required number of trays can be assembled one over the other. The position of the connecting rods in all the trays should be uniform so that any tray can be arranged on any other tray. When not in use, these can be stacked and stored.

Trolley with a large funnel

The trolley has a strong square frame, 60 x 60 x 60 cm provided with 4 sturdy legs and a large funnel. The slope of the funnel is about 45 cm and the neck of the funnel is square 5 x 5 x 10 cm. On each of the two opposite sides of the funnel, to the inner wall, two 'Connecting rods' are welded. The 'c onnecting rods'are fitted at such a distance that they will be in alignment with those fitted in the trays when arranged. Several trays can be arranged one above the other. Thus, the trolley acts as a stand for such trays. The four legs are fitted with good quality wheels so that the entire unit can be moved from one place to another.

Metal frame

It is a square metal frame, 55 x 55 cm, provided with 4 angular slots which can be inserted into the neck of the connecting rod in the tray. This is meant to be fitted to the top-most tray arranged on the trolley.

Moth collector

A plastic box with a square neck and a broad base is used for collecting the moths. This can be attached to the neck of the funnel in the trolley. Instead, a polythene bag can also be attached to the funnel with an elastic band.

Polythene cover

4 polythene sheets, each 6 ft x 2.25 ft or of any required size, are stitched together so as to get a large square bag. A strip of mosquito-net cloth may be used to join one piece with the other. This provides aeration. If a ready-made polythene bag of the required size is available, it can also be used. Pin-pricks may be made in the bag on all sides for aeration. The polythene bag is meant for enclosing all the trays that are arranged on the trolley.

Assembling the unit (Fig. 1)

- Each tray is filled with 4,000 gms of crushed grains and thoroughly mixed with about 4,000 eggs of C. cephalonica. In a separate study conducted with various diets such as sorghum, rice, maize and groundnut, bajra (pearl millet) was found to be the most economical and ideal. The other grains may also be used as per availability and convenience. Another study revealed that the eggs-to-diet in the ratio of 1:1 gave the most satisfactory results.

- 12 such trays are assembled one above the other with the help of 'Connecting rods' on the trolley as described above. When so arranged, there will be a gap of about 4.0 cm between the trays and also between the first tray and the mouth of the funnel. The number of trays in a trolley may be increased or decreased depending upon the convenience for handling.

- The top-most tray is fitted with the 'Metal frame' and then the entire unit is covered with a polythene bag open at open ends. The top-end of the polythene bag is closed with an elastic band and the other end is tucked into the frame of the trolley. There will be enough gap between the trays and polythene bag on all sides as shown in the figure. The strips of mosquito net or pin-holes provided in the polythene bag provide for aeration.

- Attach the 'Moth collector' to the neck of the funnel.

After assembling the unit as described above, keep it in rearing room for moth emergence. Several such units may be arranged one by the side of the other depending upon the production plans. A photograph of a fully assembled unit is given in Fig. 1.

Fig. 2.

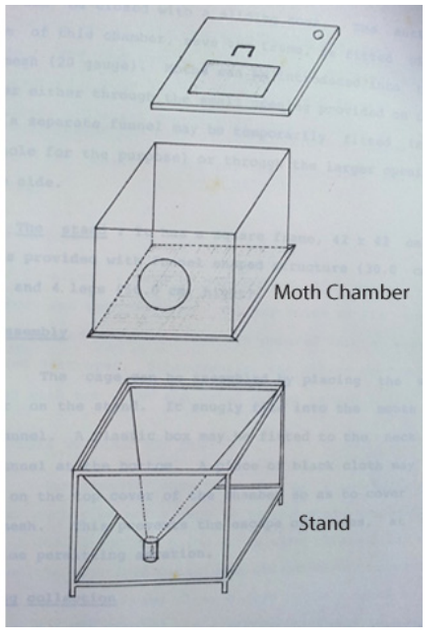


Fig. 2a.

Fig. 2. Corcyra egg-laying cage with automatic egg collection device

2. Oviposition (or Egg-laying) cage

The oviposition cage is comprised of the following components (Figs. 2 & 2a):

Moth holding chamber, A stand with a funnel and Egg collector.

Moth holding chamber

The moth holding chamber is a square box, 40 x 40 x 20 cm, made of zinc sheet. The top cover is completely detachable. It is fitted with wire-mesh (20 gauge), 30 x 20 cm, for ventilation and also egg-laying. On the right side corner at the back of the chamber, it has a hole, 5.0 cm dia, which is provided with a sliding lid. On the other side of the chamber, a 10 cm dia. opening is provided which can be closed with a sliding door. The entire bottom of the chamber, save the frame, is fitted with wire-mesh (20 gauge). Moths can be introduced into the chamber either through the small or large opening by sliding the lid.

The stand with a funnel

It has a square frame, 42 x 42 cm, provided with a funnel shaped structure at the bottom, 30 cm slope, and mounted on 4 legs (50 cm height).

Egg collector

It is a plastic box attached to the neck of the funnel at the bottom for egg collection.

Assembling the oviposition cage (Fig. 2)

- The moth chamber should be placed on the stand where it snugly fits into the mouth of the funnel. Up to 3,000 moths may be released into this chamber for egg-laying.
- A piece of black cloth may be spread on top of the chamber to cover the wire-mesh. This prevents the escape of scales while providing aeration. Eggs are also laid on the inner side of the cloth through the mesh.
- The egg collector is attached to the bottom of the funnel for automatic egg collection.

When so assembled, the oviposition cage looks like a single unit (Fig. 2). The eggs laid by the moths loosely in the chamber pass through the mesh at the bottom and get automatically collected in the 'Egg collector.'

3. Evaluation of diet preference, reproductive biology and economic parameter

A pure culture of *C. cephalonica*, was established in the laboratory, using crushed sorghum grains as food, from a nucleus stock of eggs obtained from Bio-Control Research Laboratories, Pest Control (India) Ltd., Bangalore (India). The population emanating from this stock was utilized for making studies on diet preferences and reproductive biology of *C. cephalonica* that are helpful in standardizing various parameters for optimum production. All

the studies were conducted at room temperature, 28 ± 2^0 C and 70 ± 5% R.H. These included: a) food preference by *C. cephalonica* between various grains; b) studies on insect/diet ratio on development and moth emergence; c) influence of diet when offered in a single dose and split doses on development; d) impact of adult feeding; e) impact of number of moths per cage on egg-laying; and f) reproductive biology of *C. cephalonica.* Basedon such information, g) plans and procedures for a daily production of 25 to 100 CC eggs of *C. cephalonica* are provided along with the h) non-recurring and recurring resources required. Further, i) a floor plan of an insectary for mass-production of *C. cephalonica* is indicated.

RESULT AND DISCUSSION

The results obtained with 1) *C. cephalonica* larval rearing units with automatic moth collection device, 2) oviposition cage with automatic egg-collection device and 3) various biological studies are described and discussed below.

1. Results with *Corcyra* larval rearing unit with automatic moth collection device

- When the larval rearing trays (say 12), each containing 4,000 gms of crushed grains (bajra) mixed with 4,000 eggs of C. cephalonica, are assembled on the trolley and covered with a polythene bag as described above, there is no need to handle the unit any further until moth emergence commences from 30 to 35 days after infestation.
- Moths emerging from the open trays fly out and try to sit on the polythene bag. Being slippery, they drop and get collected in the moth collector at the base of the unit. Over 90% of the emerging moths thus get automatically collected. Others can also be collected by gently tapping the bag from outside.
- Detach the moth collector and transfer the moths to oviposition cage daily in the morning.
- A unit remains productive for up to 45-50 days. Thereafter, it may be dismantled, cleaned and reused.

Advantages with the new C. cephalonica mass breeding system

- Automatic moth collection device; over 75% labour saving.
- Being an enclosed structure, it prevents the moths and scales from escaping; also prevents contamination and inhalation of scales.
- The C. cephalonica infested cages are protected from intruders like stored grain pests and also natural enemies of C. cephalonica like Bracon hebetor, etc.
- Since the unit is made of metal, it is durable and requires only one-time investment resulting in long range economic benefits.
- No separate lid is required for each tray.
- Assembling and dismantling the unit is very easy.
- Each unit is provided with wheels. Easy to move.
- Except for the polythene bags which may have to be discarded after some use, no other recurring expenses on the unit.
- Cleaning the unit is easy.
- The extra trollies and trays can be stacked one above the other and stored. The 'Connecting rods' can also be stored easily.

More than 50 units were set up at a time and tested repeatedly and found to be very convenient.

2. Results with oviposition and egg collection

- When the egg-laying unit is set up as described above and up to 3,000 moths were released into a chamber, eggs were obtained from the next day. As described later, it has been experimentally proved that feeding the moths with diluted honey or water has no influence on the longevity, fecundity or oviposition pattern. Therefore, there is no need to provide any food for moths.
- Eggs laid loosely by the moths, along with scales and other debris, pass through the wire-mesh at the bottom of the chamber and get automatically collected in the plastic box or 'Egg collector.'
- Over 90% eggs would be thus laid and collected. A small quantity of eggs may also be laid on the mesh and also on the inner side of the black cloth through the mesh. These can be dislodged and collected by gently brushing.
- The box may be detached every morning, eggs removed and cleaned.

Advantages with the new oviposition cage:

- Introduction of moths into or removal from the cage is easy.
- Up to 3,000 moths may be used at a time in a single cage for oviposition.

- Eggs get automatically collected in a separate box below.
- Eggs can be collected without disturbing the moths.
- The cages are made of metal and quite durable.
- The top cover can be detached and the inner walls of the chamber easily cleaned.
- No scope for scales or moths to escape.

The number of cages required for a production unit depends upon the daily production of moths. However, it may be remembered that for every 3,000 or less moths produced, one oviposition cage is required and that a cage can be re-cycled after every 4th day.

Egg cleaning (Fig. 3)

A simple technique has been developed for cleaning the eggs that are usually contaminated with moth scales, broken legs and other debris. The contaminated eggs are spread in a tray and the tray covered with a frame fitted with fine wire mesh (100 gauge). The mesh is kept very close to the eggs. With the help of vacuum cleaner, only the scales are sucked through the mesh while the eggs remain in the tray.

Fig. 3. Corcyra egg cleaning device with vacuum cleaner and sieves

Such eggs are then passed through a multi-layered sieve fitted with mesh (40, 60 and 80 gauge) to remove the remaining scales, broken legs, etc. For further cleaning, the eggs are gradually poured on a smooth, slope surface of a cardboard. When gently tapped, only the eggs roll down while the flat particles are left behind. Thus, pure *C. cephalonica* eggs are obtained.

Egg count

The eggs of *C. cephalonica* were measured volumetrically by using a measuring cylinder or by weighing. The volume and weight of 1 cc of fresh eggs (less than 12 hours) and their changes after 24 hours and 48 hours were measured and the data are presented in Table 1.

Table 1. Effect of ageing on the weight and volume of *Corcyra cephalonica* eggs

Age of Corcyra eggs	Volume in cc.	Weight in gms.
Fresh eggs (less than 12 hours)	1.000	0.5832
After 24 hrs.	0.975	0.5680
After 48 hrs.	0.950	0.5520

It can be seen from the table that as the eggs aged, their volume as well as weight decreased. When freshly laid eggs (less than 12 hours old) were measured in the morning, their number ranged from 15,000 to 18,000 with an average 16,000 eggs per cc . But, one day or 24 hours later, the eggs numbered 16,500 eggs/cc while two-day or 48 hours later they numbered 17,000 eggs/cc. Such higher count encountered with older eggs was obviously due to shrinkage of eggs with age.

Egg sterilization

A UV chamber has been specially designed for the purpose (Fig. 4). The chamber, made of plywood, measured 75 cm (length) x 45 cm (width) x 45 cm (height). It is provided with a door in front. The roof of the chamber is fitted with a lamp shade to which a 15W UV tube (40 cm) is fixed.

Fig. 4. Corcyra egg sterilization chamber fitted with UV lamp

C. cephalonica eggs were thinly spread in a tray and the tray was placed inside on the floor of the chamber. The distance between the eggs in the tray and the UV tube was maintained at about 15.0 cm. The lid of the chamber was closed and the bulb switched on for about 45 minutes. This treatment resulted in 100% sterilisation of the eggs, thereby preventing their hatching, yet suitable for parasitisation by *Trichogramma*. This prevents the possibility of the unparasitized *C. cephalonica* eggs from hatching and the larvae destroying the parasitized eggs.

Egg storage

Irradiated *C. cephalonica* eggs were stored at 5^0C to study the fitness of stored eggs for parasitization by *Trichogramma*. The extent of parasitization was 95%, 95%, 80%, 75%, 60% and 30% on the 1st to 6th day after storage, respectively. It is evident that as the storage period increased, the rate of parasitism declined.

The eggs of *C. cephalonica* were also stored at 5^0C without irradiation and tested for their acceptability by *Trichogramma*. Such eggs stored for beyond 3 days recorded less than 30% parasitization. Such poor result was mainly due to shrinkage of eggs. This indicates that irradiation is advantageous.

3. Results with studies on diet preferences and reproductive biology.

a) Food preference studies

Three varieties of jowar, rice, wheat and groundnut, classified as low, medium and fine depending upon their quality, and two varieties of bajra, were tested for their preference by *C. cephalonica*. These were offered as whole grains and also as crushed grains to study their relative merit. There were altogether 28 treatments, each with 3 replications. In each treatment, 2 kg. grains of each type were uniformly mixed with about 2,000 eggs of *C. cephalonica* in a round zinc container and reared till the moths emerged. In all the experiments, the larvae showed preference for fine quality grains. The data on the per cent emergence of moths in various grains of fine quality, crushed as well as whole grains, are presented in Table 2.

Table 2. Food preference between whole grains and crushed grains by *Corcyra cephanolica*

Type of grains	Per cent emergence of moths (3 replications each with 2000 eggs mixed with 2000 gms of crushed grains)				
	Sorghum	Rice	Wheat	Groundnut	Bajra
Whole grains.	3.74	18.91	7.11	18.71	19.45
Crushed grains	11.61	17.27	20.97	63.87	40.81
CD *P*=0.05	0.79				

It is evident from the moth emergence data that *C. cephalonica* larvae significantly preferred crushed grains to whole grains in all cases except rice where the difference between the two was non-significant. The highest number of moths obtained from various crushed grains was in the following order: groundnut (63.87%), bajra (40.1%), wheat (20.97%), rice (17.275) and sorghum (11.61%).

In a separate study carried out on the influence of larval diet on fecundity, it was found that the moths from the crushed groundnut recorded the highest fecundity (387.3 per female) followed by crushed bajra (371.53), sorghum (304.87), rice (229.47) and wheat (218.40).

The cost of 1 kg. fine variety of rice, wheat, sorghum and bajra was more or less comparable while that of groundnut was about four times higher. Thus, although groundnut yielded more moths with higher fecundity, it was not commensurate with its high cost. Both from the quantitative and economic points of view, crushed bajra can be considered as the most suitable diet for the production of C. cephalonica.

b) Studies on insect/diet ratio on development and moth emergence

To determine the proper egg to diet ratio for optimum production of *C. cephalonica*, the following four different ratios were used: A) 4,000 eggs : 4,000 gms of diet (1:1); B) 8,000 eggs : 4,000 gms of diet (2:1); C) 12,000 eggs : 4,000 gms of diet (3:1); and D) 16,000 eggs : 4,000 gms diet (4:1). In other words, keeping the quantity of grains constant, only the quantity of eggs was varied. Each treatment was replicated three times. Crushed bajra was used as the diet and round zinc containers, 45 cms. dia. and 7 cms. height, covered with lid were used for rearing. The studies were conducted at 28 + 20 and 75 + 5% R.H. The insect was reared from egg to adult emergence and the number of moths emerged has been taken as the index to identify the optimum insect/diet ratio. The results obtained with the number of moths emerged in each treatment are presented in Table 3 and the pattern of moth emergence in Fig. 5.

Table 3. Effect of different ratios of eggs to diet (crushed bajra) on development of *Corcyra cephalonica*

Parameters / Ratio	A (1 :1)	B (1 : 2)	C (1 : 3)	D (1 : 4)
Qty of diet per tray in gm.	4,000	4,000	4,000	4,000
Qty of eggs per tray in nos.	4,000	8,000	12,000	16,000
No. of trays observed	3	3	3	3
Total no. of moths obtained	9,196	6,220	2,861	2,258
Av. yield of moths/tray out of 4,000	3,065	2,073	954	753
Av. yield of moths / tray	76.6%	25.9%	8.0%	4.7%
Day of first moth emergence	34th	39th	40th	50th

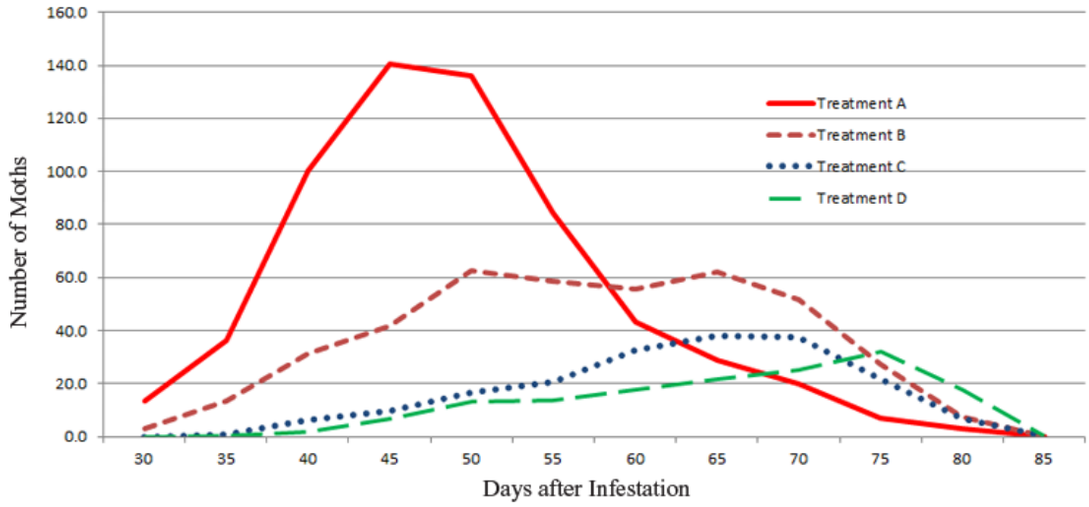
No. of days (from day of egg infestation) required for:				
25% moth emergence	49	61	69	81
50% moth emergence	54	69	76	90
75% moth emergence	61	78	83	97
100% moth emergence	91	95	97	108
Av. yield of moths/tray/day	54	37	17	13

No. of moths emerged (Table 3):

It can be seen from the table that there was significant variation in the number of moths emerged between the treatments. The maximum emergence of 76.63% moths was recorded in treatment 'A' where the number of eggs added to the diet was the least i.e., 4,000 eggs to 4,000 gms of bajra. On the contrary, the poorest emergence i.e., 4.7% was recorded in the treatment where 16,000 eggs were seeded with 4,000 gms of bajra. Thus, the data revealed that as the egg density increased, the % of moth emergence decreased. It can also be seen from Table 3 that the first emergence of moths commenced on the 34th, 39th, 40th and 50th day after infestation and the mean yield of moths/tray/day was 54, 37, 17 and 13 in the treatments where 4,000, 8,000, 12,000 and 16,000 eggs were seeded each with 4,000 gms of the diet, respectively. This revealed that higher the density of eggs, longer would be the life cycle and poorer would be the final output of moths. Since in the treatment 'A' (4,000 eggs : 4,000 gms diet), the life cycle of the insect was completed faster with better production and survival rates, this 1 : 1 ratio may be considered as optimum. In other words, 1 egg : 1.0 gm (or 100 eggs : 100 gms) diet seems to be the ideal proportion for mass production of *C. cephalonica*.

Pattern of moth emergence (Fig. 5):

The daily rate of moth emergence was recorded from each of the four treatments (with three replications) which comprised A) 4,000, B) 8,000, C) 12,000 and D) 16,000 eggs seeded with 4,000 gms of diet (crushed bajra). The data, pooled for every 5 days up to 50 days of emergence or from the 35th day to the 85th day of infestation, are presented in Fig. 5.



Days after Infestation	30	35	40	45	50	55	60	65	70	75	80	85
A= 1000 eggs: 1000 diet	13.3	36.2	100.5	140.6	136.1	84.7	43.1	28.8	19.7	6.9	3.1	0.1
B= 1000 eggs: 2000 diet	3.2	13.2	31.3	41.7	62.7	58.5	55.7	61.9	51.7	27.2	7.3	0.2
C= 1000 eggs: 3000 diet	0.0	1.0	6.1	9.5	16.7	20.5	32.7	38.2	37.3	21.8	6.5	0.3
D= 1000 eggs: 4000 diet	0.0	0.2	2.0	6.7	13.3	13.8	17.5	21.4	25.3	32.0	17.9	0.1

Eggs in numbers; diet in grams

Fig. 5. *Corcyra cephalonica* : Daily rate of moth emergence

It can be seen from the data that the maximum number of moths/tray/day obtained in treatment 'A' was 140.60 which was significantly higher than that obtained in other treatments i.e., 69.93 in 'B', 38.2 in 'C' and 32.0 in 'D.'

The data further revealed that in treatment 'A', 75.38% of the moths (3017) emerged within 45-50 days after infestation (or within 10 to 15 days after the first moths emerged). The emergence continued up to 60 days, but the number was meagre. So, it is better to terminate such cages after 50 days as otherwise it would be unproductive. Such cages, after cleaning, can be reused for further breeding purpose.

In treatment 'B', the number of days taken to yield maximum moths i.e., 2035.67 (25.45%) was 50 days. Similar were the results with treatment 'C' (952.33, 7.94%) and 'D' (749.33, 4.68%). Therefore, based on the pattern of moth emergence, treatment 'A' can be considered as the best as in this case, the insect completed its life cycle quickly with good production.

c) Influence of diet when provided in single dose and split doses

Experiments were conducted to study whether, while mass-rearing *C. cephalonica*, it is advantageous to provide the required quantity of the diet in the rearing containers in a single dose or in split doses at interval. Two studies were carried out each with 4,000 eggs of *C. cephalonica*. In one, 4,000 gms of crushed bajra were provided in a single dose (mixed with eggs) whereas in another, only 250 gms were provided in the first batch for the first 18 days and the remaining 3,750 gms were added later. Each treatment had 40 replications. Data on the duration for completing the life cycle and total moths emerged in the treatments were recorded for comparison. These are presented in Table 4.

Table 4. Influence of diet (crushed bajra) provided as a single dose and two split doses on the development of *Corcyra cephalonica*

No. of eggs per tray	Quantity and mode of diet provided per tray	Av. moths emerged per tray*	Per cent emergence of moths per tray	No. of days taken for moth emergence	
				First moth	Last moth
4,000	4,000 gms in a SINGLE DOSE	2,366.25 (+671.815)	59.16	40	94
4,000	4,000 gms in TWO SPLIT DOSES of 250 gms along with eggs and 3,750 gms on 18th day	661.13 (+205.38)	16.53	52	120
CD *P*= 0.05	220.48				

*Values are mean of 40 replications.

The data revealed that the treatment in which the full quantity of food was provided in a single dose at the egg stage of the insect itself, the first moth emergence occurred on the 40th day and the emergence continued up to 94 days from the day of infestation. On the other hand, in the second treatment where the food was provided in two split doses, the first emergence of moths commenced after 50 days and it continued up to 120 days. These results indicated that the life cycle was completed faster when the food was provided in a single dose. Single dose was also superior to split doses in terms of higher moth yields i.e., 2366.25 moth/tray as against 661.13 moths/tray. The % of insects that successfully completed their development was also higher in single dose (59.16%) than in split dose (16.13%). Thus, it is advantageous to provide food in a single dose. It also saves considerable labour.

d) Studies on adult feeding

Studies were conducted to determine whether *C. cephalonica* moths required feeding for their longevity and to express their full reproductive potential. Two sets of moths, one provided with no food and the other provided with 50% aqueous honey solution in cotton swabs, were studied. Each set had 15 moths. The results are presented in Table 5.

Table 5. Impact of feeding the moths on the fecundity and longevity of *Corcyra*

	Total eggs laid	Ovarian eggs after death	Total fecundity	Longevity in days
With food: 50% aqueous honey as food to female moths	360.53 (86 – 586)	104.13 (15 – 289)	464.67 (358 – 620)	8.6 (6 – 14)
Without food for females moths	400.33 (180 – 600)	67.67 (19 – 191)	468.00 (306 – 619)	9.2 (3 – 18)
CD *P*=0.05	NS			

*Values are mean of 15 replications (values in parenthesis indicate the range).

The average fecundity of the females fed with 50% honey solution was 464.67 per female as against 468.0 per females for unfed females. The ovarian eggs (eggs found in the ovary after dissecting the dead moths) were added in both the cases. There was no significant difference between the two. The longevity of fed females was 8.68 days while it was 9.2 days for unfed females. These results bring out an important fact that there is no need to provide any feeding to moths during mass-production. This saves considerable labour as well as honey and money.

e) Impact of number of moths per cage on egg-laying

Experiments were conducted to standardise the optimum number of moths to be released in an oviposition cage to secure good oviposition. 2,000, 3,000, 4,000 and 5,000 moths were released in each cage and the eggs laid daily were collected and measured. The results are presented in Table 6.

Table 6. Quantity of eggs laid in relation to number of moths released in an oviposition cage

Day of oviposition	No. of moths released per cage & quantity of eggs obtained in cc (1cc = 16,000 eggs)			
	2,000	3,000	4,000	5,000
1st day	11.6	16.5	12.4	10.0
2nd day	7.5	7.0	8.0	6.0
3rd day	2.1	2.0	1.5	1.5
4th day	0.1	0.6	0.3	0.5
Total eggs in cc	21.3	26.1	22.2	18.0

It can be seen from the data that the best results were obtained with 2,000 and 3,000 moths/cage, yielding 21.3 and 26.1 CC of eggs, respectively. Inspite of releasing 4,000 and 5,000 moths in other cages, the eggs obtained were far below expectation. This negative result is obviously due to over-crowding. 3,000 moths per cage is considered optimum in mass production programmes.

f) Reproductive biology of Corcyra cephalonica

During the course of various experiments, observations were also made on the biology of *C. cephalonica*. Crushed bajra was used as the diet and the studies were made at 28 ± 2^0 C and 75 + 5% R.H.

The *C. cephalonica* moths are mainly nocturnal which seek corners, shaded walls and heaps of food for shelter. They are quite sluggish and reluctant to fly. Therefore, they can be easily captured. When the moths are resting, their sex can be easily distinguished mainly by the difference in the head region: the head of the female is elongate with a nose-like projection due to projected palp whereas in male it is blunt and less conspicuous.

Mating occurs readily. There was no difference in the fecundity between the moths that were fed with 50% aqueous honey solution and those that were starved.

The eggs are laid loosely. They are small and somewhat elliptical with blunt ends. Length varied from 0.5 to 0.64 mm and width from 0.33 to 0.36 mm. Freshly laid eggs are white. When viewed under microscope, irregularly sculptured surface can be seen. Observations made on various aspects of biology are summarised in Table 7.

Table 7. Reproductive biology of *Corcyra cephalonica* at 28+2 C and R.H. 70+5%

Characters observed	Male	Female
Egg incubation period (in days)	4.58	4.69
Larval period (in days):		
1st instar	4.42	4.19
2nd instar	5.04	4.92
3rd instar	3.46	3.73
4th instar	3.42	3.27
5th instar	5.21	5.12
6th instar	8.42	9.69
Total larval period	29.97	30.92
Pupal period	15.86	15.08
Total days from egg to adult emergence	50.41	50.69
Adult longevity (in days):		
Mated	5.53	9.38
Unmated	9.58	10.73
Mean fecundity (no. of eggs per female)	466.34	
Pre-oviposition period	1.35 days	
Oviposition period	7.70 days	
Post-oviposition period	0.33 day	
Incubation period	4.0 days	
Egg hatching	93.00%	
Pupal formation	89.00%	
Adult emergence	95.00%	
Sex ratio	1.00 male : 1.5 female	

It can be seen from the table that the mean egg period was 4.58 and 4.69 days, larval period 29.97 and 30.92 days and pupal period 15.86 and 15.08 days for males and fe-

males, respectively, based on 100 samples each. The total development from egg to moth emergence was completed in about 50 days. The mean fecundity was 466.34/female and the sex ratio was 1 male : 1.5 female. This information on reproductive biology is helpful in planning the mass-production of *C. cephalonica*. Such biological studies were made earlier by several including those by Parameshwar and Jai Rao (1987a and b).

g) Production plans and procedure

A carefully planned production and assured supply of the required quantity of eggs/larvae of *C. cephalonica* are of vital importance for effectively executing the production of *Trichogramma* and other parasitoids and predators. Based on the experimental results and experience gained, the following production schedules have been worked out:

i) Procure the required quantity of good quality grains i.e., bajra, sorghum, etc., as the case may be, at least 15 days in advance.

ii) Make sure that the grains had not been recently treated with chemical insecticides. To test, take about 100 gms from each lot/bag and crush the grains into 2 to 3 pieces each. Release about 25 first or second instar larvae of C. cephalonica and allow them to feed for 2 to 4 days. If the larvae survive, the grains are safe. In any case, to be on the safer side, it is advisable to use grains 7 to 10 days after procuring the same from the market.

iii) The required quantity of grains should be coarsely milled such that each grain gets split into 2 to 3 pieces.

iv) Sterilize the grains at 100^0 C for about 30 minutes to kill the contaminant organisms, if any.

v) Cool the grains at room temperature and then spray 0.1% formalin. This restores grain moisture while at the same time preventing fungal infection.

vi) Air-dry the grains.

vii) Add the selected grains at the rate of 4 kg/tray and mix them with about 4,000 C. cephalonica eggs (~0.25 CC). (The number of trays to be infested daily depends upon the extent of production planned).

viii) Assemble the infested trays (say 12) in the trolley and cover them with polythene bag.

ix) Attach the 'Moth collector' to the neck of the funnel in the trolley.

x) Once the unit is thus set up, it may be left as such until the moth emergence commences from about the 30^{th} day onwards. Moths get automatically collected daily in 'Moth collector.'

xi) Transfer the moths daily to the oviposition cage. Eggs get automatically collected in the 'Egg collector.'

xii) Collect and clean the eggs daily and measure.

xiii) A small part of the production may be set aside for further infestation while the remaining eggs may be sterilized and used for Trichogramma production.

xiv) Carefully monitor the rearing rooms once in 4-5 days for presence of Bracon hebetor or other intruders and destroy them. Operating a light trap, preferably 'Pest-O-Flash®' (electrical flying insect killer), for about one hour, was found to be helpful in attracting insects and killing them.

Plans for daily production of 25 CC/100 CC eggs of *Corcyra cephalonica*

Experiments conducted have revealed that a tray containing 4 kg of grains and seeded with about 4,000 eggs of *C. cephalonica* yielded a mean of 54 moths per day for a period of 57 days between 34 and 91 days after infestation (Table 3). Four trays, thus infested, would yield altogether over 200 moths/day. Such infestation at the rate of 4 trays/day should be continued for 90 days so as to accumulate 360 trays. Of these, by the 90th day, 240 trays infested from the 1st to the 60th day would be yielding the moths daily while in the remaining 120 trays *C. cephalonica* will be still in the developing stage.

A total of over 12,000 moths can be obtained daily from 240 trays @ 50 plus moths/tray from the 90^{th} day onwards. If the infestation @ 4 trays/day is continued on a regular basis, the production of 12,000 moths/day will be stabilized.

After 90 days from the date of infestation, the production of moths in a tray becomes meagre. Such trays may be cleaned and reused.

Moths can be collected daily and transferred to oviposition cages at the rate of 3,000 moths/cage. 3,000 moths yield 25 CC eggs at the rate of 15, 8 and 2 CC in a span of 3 days. 25 CC of eggs can be harvested from the 4th day onwards if 3,000 moths are left daily for oviposition as depicted in Table 8.

Table 8. Reproductive biology of *Corcyra cephalonica* at 28+2 C and R.H. 70+5%

Days	No. of moths arranged per day		Days / quantity of eggs obtained in cc						
	Daily	Cumu-iative	1	2	3	4	5	6	7...
1	3,000	3,000	15	8	2				
2	3,000	6,000		15	8	2			
3	3,000	9,000			15	8	2		
4	3,000	12,000				15	8	2	
5	3,000	12,000					15	8	2
6	3,000	12,000						15	8...
					25	25	25	25	

To secure 100 CC of eggs per day, we require 12,000 moths daily. After the 4th day, the moths can be discarded as they become unproductive. Egg-laying cage can be cleaned with boiled water and dried before re-use.

Of the 100 of eggs produced daily, only 1.00 CC (about 16,000 eggs) can be set apart for fresh infestation while the remaining quantity can be used for the production of *Trichogramma*, etc.

h) Economics of mass-production

Experiments conducted have provided information on the pattern of moth emergence and egg production (Tables 3 & 8 and Fig. 5).

i) Floor plan of an insectary for mass-production of C. cephalonica

To be successful in mass-production of an insect, a well-planned insectary with temperature and humidity control is necessary. The extent of space and type of equipment required depend upon the type of natural enemies and their hosts to be cultured as well as their production size. Some general ideas and facilities required for a biological control laboratory are given by DeBach (1964), Fisher and Finney (1964), King and Leppla (1984) and Manjunath (1985).

The general equipment required for mass-production of *C. cephalonica* are listed in Table 9. With regard to the building, it can be a simple structure with adequate rooms for the following purposes:

- Grain Storage Room (GSR) – For storage of bajra, sorghum, etc. procured form the market.
- Heat Sterilization Room (HSR) – This is equipped with Hot Air Oven for sterilizing the grains before use.
- Larval Rearing Room (LRR) – The infested trays are kept in this room for up to 30 days after infestation.
- Moth Emergence Room (MER) – The infested trays, about 30 days after infestation, are shifted to this room.
- Oviposition Room (OVR) – The egg-laying cages are arranged in this room.
- Egg Cleaning Room (ECR).
- General Store (GS) – For storage of extra trays, trollies, cages, etc.
- Cleaning Room (CR) – For cleaning cages, etc.
- Office Room (OR).
- Toilet and Wash (TW).
- Extra Room (ER).

The suggested floor plan of a building is indicated in Fig. 6.

The building should be ideally located in an area free from undesirable environmental pollution. The building should stretch East-West or be oriented in such a way as to avoid , as far as possible, direct sunlight into the rooms. The wall of the culture rooms facing north or south may be fitted with strong and protected windows and provided with louvers so as to allow only the reflected light into the rooms and to avoid direct sunlight. Provision for installing air-conditioners may also be made in the wall. The windows may be fitted with two layered mesh. This prevents the entry of *Bracon hebetor* and other intruders.

The rooms may be fitted with double doors provided with automatic door closers. Well-planned, step-by-step daily operations in each room may be followed to minimise the movement into and out of the culture rooms. This not only increases the work efficiency of the staff, but also minimises the chances of other organisms entering the culture rooms.

The value of biological control in pest management has been well-appreciated. In spite of it, the method has not found as much practical application as it deserves to

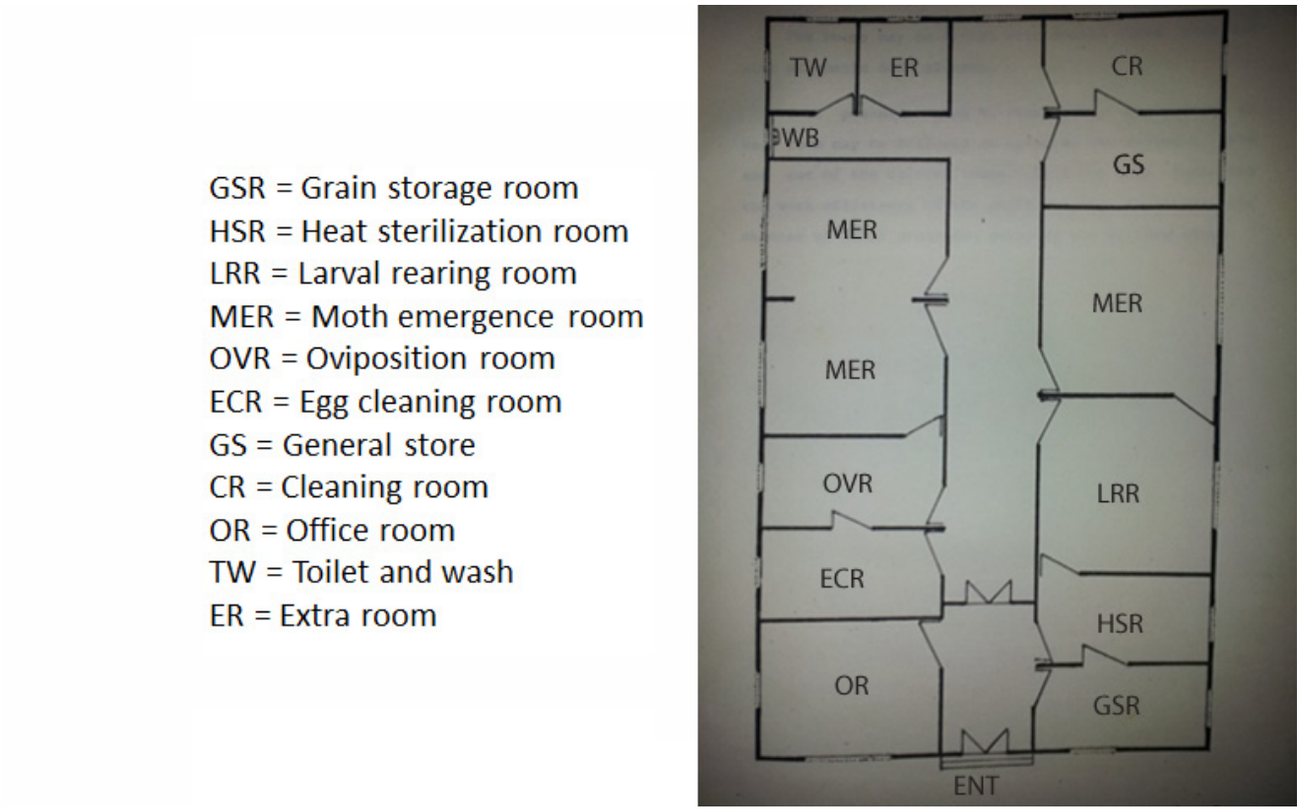


Fig. 6. Floor plan of an insectary for *Corcyra* production

be. One of the main reasons for it is the difficulty in mass-producing the natural enemies at economic cost and making these available in adequate quantities for timely releases. More often, the success of mass-production of natural enemies is dependent on the successful production of its original or factitious host. In this respect, the value of *C. cephalonica,* which serves as a laboratory host for a wide range of natural enemies – over 75 species – is unmatched (Manjunath, 1993). For example, but for *C. cephalonica*, the egg parasitoids, *Trichogramma* spp., would not have found such a wide application in biological control in India as also in several other countries.

Although *C. cephalonica* is an old insect and has been studied and multiplied since several decades, there has not been any significant breakthrough in its mass-production technology. In fact, while there are numerous publications on biological and other aspects of *C. cephalonica,* those dealing with its production technique are hardly a few. Perhaps, those engaged in its production seem to have learnt to live with certain regular problems associated with it such as moth collection, scale contamination, cross infestation, parasitisation by *Bracon hebetor*, etc. However, in view of the increasing importance being given to biological control in integrated pest management, there would be a huge demand for natural enemies. Therefore, a versatile laboratory host like *C. cephalonica* should be fully exploited. A well-planned mass-production technique is a pre-requisite to achieve this.

One of the earliest methods adopted for breeding *C. cephalonica* was by using small wooden boxes or trays (Subramanian and Rao, 1940). The moths that emerged in these containers were collected manually in tubes. This was a tiresome and highly time consuming method. Besides, the workers were directly exposed to the scales, a known health hazard. Jalali and Singh (1989) used a vacuum cleaner for moth collection and claimed that it increased collection efficiency by 33%. However, this technique has its limitations in a truly mass-production unit as a considerable number of moths escaped and those caught were often damaged or killed due to air pressure. Parshad (1975) designed a new structure, aimed at semi-automatic collection of moths. It was a novel approach, but it was not full-proof and also accumulation of moisture and heat within the structure hampered its efficiency. However, it triggered the imagination for the present work.

The new *C. cephalonica* breeding device developed presently is aimed at overcoming most of the major prob-

lems encountered in a *C. cephalonica* production unit. So is the contribution of the new oviposition cage. The most important features of these cages are that the moth collection or egg collection is automatic, scales and moths are prevented from escaping, the units can be easily dismantled and stored, and being made of metal, these are quite durable. These have been tested in the laboratory for several years and found to work quite satisfactorily. It is a significant breakthrough.

With regard to the diet, a number of products like cereals, pulses, spices, oilseeds, dried fruits, etc. were tested, both in India and other countries (Katiyar, 1962, Kamel *et al.,* 1977; Sharma *et al.,* 1978; Medina and Cadapan, 1982). Several of these were only of academic interest. But, during the present studies, only those diets that are procurable and reasonably priced have been tested from the practical point of view. These included bajra, groundnut, rice, sorghum and wheat.

Fine, medium and low quality grains available in the market were tested, both as whole grains and also in the crushed form. In all the cases, the insect preferred fine quality grains. Further, they showed a clear preference to crushed grains over whole grains (Table 2). In fact, their development on whole grains was very poor. SeshagiriRao (1954) also had reported similar observations.

Of the five diets tested, groundnut gave seemingly more impressive results than the others. It recorded 63.87% moth emergence (Table 2) and a mean fecundity of 387.8/ female which were higher than the results obtained with other diets. During the present studies, bajra was found to be next to groundnut in respect of moth emergence (40.81%), fecundity (371.53/female), etc. Despite, if we consider the cost of groundnut which is about 4 times more than that of bajra,the latter seems to be preferable over groundnut from the economic point of view. Further, bajra is less susceptible to natural attack by storage pests as compared to groundnut. Besides, groundnut is more vulnerable to pilferage.

Several earlier workers rated sorghum as the most preferred diet by *C. cephalonica* (Katiyar, 1962; Seshagiri Rao 1954) when they evaluated it along with other diets like wheat, maize, groundnut, rice, etc. However, during the present investigation, sorghum was found next to groundnut and bajra. The results with rice were not encouraging. This was rather surprising since the original diet of *C. cephalonica* is presumed to be rice and, therefore, it is popularly called 'Rice Moth." Wheat also did not serve as a good diet for this insect.

Investigations on adult feeding revealed that the moths do not require any feeding to express their full reproductive potential. This is an important finding as it has been a routine practice to feed the moths with aqueous honey. In a mass-production programme, this helps in saving considerable time, honey and money without any compromise in production. Another finding is that over-crowding the moths in an oviposition cage has negative effect on egg-laying. This is in conformity with the findings of Etman *et al.* (1988). During the present study, 3,000 moths per cage has been found to be optimum.

Similarly, it has been found during the present studies that over-crowding the larvae in rearing trays resulted in increased larval mortality, prolonged life cycle and decrease in adult emergence and this agrees with the results obtained by Mammen and Visalakshi (1974). The present studies revealed that an egg to diet ratio of 1: 1 (i.e.,1,000 eggs to 1,000 gms or 4,000 eggs to 4,000 gms of diet) is optimum.

Studies on the reproductive biology of *C. cephalonica* brought out several important facets that would be helpful in planning its production. The fecundity was about 466 eggs/female and the effective oviposition period lasted for three days with more eggs being laid on the first day (24 hrs after emergence). The egg, larval (with six instars) and pupal periods were completed in about 4.5, 30.0 and 15.5 days, respectively, and that the life cycle from egg to adult emergence was completed in about 50 days (Table 7) at 28 $\pm$ 2^0 C and R.H. 70 $\pm$ 5%. Several studies were made in the past on the biology of *C. cephalonica* including those by Parameshwar and Jai Rao (1987a and b) and more recently by Jagadish *et al.* (2009), but they used different diets. However, there was no drastic difference. The pattern of moth emergence during the present studies indicated that it lasted from around the 34th day of infestation to about 90 days with maximum emergence taking place between 40 and 50 days (Table 3, Fig. 5). Based on the information on reproductive biology, a production schedule for a daily production of 25 to 100 CC of *C. cephalonica* eggs has been indicated.

As a laboratory host, *C. cephalonica* has several advantages: a) it is accepted as a satisfactory factitious host by a wide range of parasitoids and predators b) easy to mass-produce under normal conditions of temperature and humidity, c) facilities required are simple, d) its food media are dry, readily available and can be easily stored, e) production is economical, f) larvae are not cannibalistic, so suitable for mass-rearing, g) eggs are laid loosely and, therefore, are very convenient to collect, measure and

handle, h) eggs, larvae and pupae are sufficiently large and nutritious enough to support normal development of various parasitoids and predators, and i) serious incidence of diseases in the mass-culture is rare.

Although *C. cephalonica* is such an important insect in a biocontrol laboratory, no insectary specially designed for its mass-production has been planned and constructed so far. Generally, residential premises are hired and converted into a laboratory, making a lot of compromises in the process. A simple floor plan provided in this paper for such a laboratory, keeping the practical requirements in mind, should be very useful. It is hoped that the new technology developed and described here along with the comprehensive package of practices for mass-production of *C. cephalonica* will stimulate more interest in its production which, in turn, would pave the way for enhanced production and application of biological control agents.

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