CHAPTER ONE

MASS PRODUCTION OF *CHELONUS BLACKBURNI*

CAMERON ON HOST *PTHORIMAEAE*

*OPERCULELLA (ZELLER)*
CHAPTER 1

MASS PRODUCTION OF CHELONUS BLACKBURNI CAMERON ON HOST PHTHORIMAEA OPERCULELLA (ZELLER)

1.1 Introduction

Integrated Pest Management (IPM) is the management system that in the contest of associated environment and population dynamics of pest species, utilized all suitable techniques and methods in as compatible manner as possible and maintains pest populations at levels below those causing economic injury. It is intergradation of all suitable management techniques with natural regulating and limiting element of the environment. It is multidisciplinary approach which includes all pest management tactics coordinated in a unified programme and crop protection is considered as one aspect of agroecosystem management and addresses the economic, ecological and social issues. Integrated Pest Management through conventional techniques has often been found to be difficult under intensive and exploitative practices of crop production. This system was developed out of the need for all sustainable crop protection strategy against the background of increasing pesticide use and deleterious effect of residues on the environment (Ghorpade et.al. 2004). The intensive farming also introduced new pest problems. To overcome these problems IPM strategy is an important aspect of pest management. Considering the total cropped area, the probable requirement of the bioagents is very high. To cater the need it is necessary to promot the efforts for production of bioagents in the state, for that we have to take efforts from mass production
of important bioagents like predators and parasitoids. The parasitoids have played important role in the biosuppression of insect pests showing unnoticeable evidence of resistance as well as flareback. On the other hand, this approach of pest control does not leave toxic residue or harmful effects after application which is desirable in crops.

Vegetables being a major dietary constituent of humans are badly damaged by certain lepidopterous pests during vegetative as well reproductive stages of the crops and costs direct damage inflicting huge losses. All types of vegetables crops are most widely grown in India. Since these vegetables grown all the year round, the caterpillar pests receive the source of food throughout the year and the pest ultimately become endemic (Anonymous, 1991, 1999).

The pest control strategies till today mainly governed with the use of chemical pesticides, which posed several problems including environmental pollution and health hazards. The various chemicals insecticides effective for the control of this pest are bound to live undesirable toxic residues or in fruits, destined for human consumption also it leads to killing natural enemies of pests resulting in their resurgence and development of resistance. Thus routine insecticides application would harm the delicate balance between the insect pests and natural enemies besides increasing the cost of control majors. Hence biological separation of such pests plays an important role in this regard.

The purposes of rearing beneficial insects parasitoids in the laboratory may be to study the insect itself, to supply routinely for release for biological control. Not all insects can be reared in large numbers in the laboratory. The important qualities required in a laboratory reared insect are short life cycle, high biotic potential, simple food requirement, and alternative hosts.
Amongst different kinds of bioagents; parasitoids either monophagous or to some extent oligophagous ones are widely accepted in pest control. However parasitoids like *Chelonus blackburni* Cameron (Braconidae:Hymenoptera) is one of the dominant and bodily stout exotic parasitoid accepting parasitization in certain lepidopteran range. It is an egg – larval, endoparasitoid and uniparental parasitoid introduced from Hawaii, USA, which has fairly wide host range for lepidopetara (Raj et al., 1999). The potentials of *Chelonus blackburni* has been evaluated against few lepidoetaran pest by earlier research workers from parasitoization as well efficiency point of view. The parasitoids showed parasitism in fresh eggs of *Helicoverpa armigera* laid on the leaves of pigeon pea (*Cajanus cajan*) plant (Rangadhamaiah, et al., 1987).

Use of *C. blackburni* gave good control of cotton ballworms (Pawar and Prasad, 1985). For biocontrol purpose the large amount of parasitoid culture is required, hence mass production is an important aspect in biological control programme.

We therefore used *Phthorimaea opercuella* (Zeller) and *Corcyra cephalonica* Stanton to study the production of host insect. Hatching percentage, parasitization of host eggs by parasitoid are the main aspect for the production of alternative host. This aspect we studied in laboratory for efficient multiplication of *Chelonus blackburni* and determine the most suitable laboratory host for the mass rearing of parasitoid. So in present study, we focus on the different aspects of mass production of *C. blackburni on Phthorimaea opercuella* (Zeller) and *Corcyra Cephalonica* Stainton and in the laboratory.
1.2 Materials and Methods

Rearing of *H. armigera* larvae in the laboratory: Actively feeding *H. armigera* larvae were collected from fields (Mahatma Phule Krishi Vidyapeeth, Rahuri, India). These were maintained on chickpea based-artificial diet (AD) (Nagarkatti and Prakash, 1974) in laboratory under controlled conditions at temperature 27°C, humidity 60% and photoperiod 16:8. To ensure greater genetic homogeneity among test populations, insects were maintained on AD for three generations. The larval excrements were cleaned daily from the plastic vials and provided fresh pieces of diet. The larvae grew within two week and pupated. The pupae were collected and kept in a glass jar. The glass jar was closed with a fine muslin cloth. Two petri dishes having water soaked cotton wool were kept in the glass jar to maintain humidity.

Adult moths emerged from the pupae after 6-10 days which were collected every morning and transferred in to the glass jar and cover the glass jar with muslin cloth. Mating occurred 1–2 days after adult emergence. Adults can be sexed based on the colouration pattern of the wings. Females are chocolate brown coloured with variations in colour intensity, whereas males are pale brown. After a preoviposition period of 2 - 3 days, eggs were laid inner side of covered muslin cloth. Adults survive for 8 - 10 days life. Moths were maintained in the jar until death. Honey (10%) was provided to the adults as a food on a cotton swab at the bottom of the cage. The adult food was changed on alternate days. The eggs laid on inner side of muslin cloth were collected daily and treated with 0.1% sodium hypochloride solution and kept in a plastic box (10 × 5 cm) filled air. The eggs from each pair were kept in separate boxes. After hatching, neonate larvae were transferred into a plastic vials containing small cubes of AD. Ones larvae
become cannibastics, they were transferred individually into separate plastic vials. Experiments were conducted by feeding *H. armigera* larvae on artificial diet. Ingredients required to prepare AD is given in Table 2.2.1

**Table 2.2.1. Composition of AD used to rear *H. armigera* under laboratory conditions.**

<table>
<thead>
<tr>
<th>Part A</th>
<th>Quantity (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chick pea flour</td>
<td>105</td>
</tr>
<tr>
<td>Methyl-4-hydrocyl benzoate</td>
<td>2.00</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>3.25</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>1.00</td>
</tr>
<tr>
<td>Streptonic sulphate</td>
<td>0.25</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>2 Capsules</td>
</tr>
<tr>
<td>Multivitamin tablet</td>
<td>2 tablets</td>
</tr>
<tr>
<td>Formalin (10%)</td>
<td>4.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agar-agar</td>
<td>12.75</td>
</tr>
<tr>
<td>Yeast</td>
<td>10.00</td>
</tr>
</tbody>
</table>

These whole Ingredients were prepared in 780 ml of water. Entire diet ingredients of part A were mixed thoroughly in a mixing bowl to avoid clot formation. Methyl-4-hydroxyl benzoate being insoluble in water was dissolve in ethyl alcohol. This was boiled on hot plate by adding 150 ml distilled water. For Part B agar was sprinkled in boiling water.
with continuous stirring and then yeast was sprinkled. After removing the ingredients from the hot plate part A and part B were mixed quickly to avoid solidification. The prepared diet was poured in tray and kept in refrigerator.

**Hatching percentage of *H. armigera***:

Total 100 fresh eggs in five different lots were maintained separately and numbers of eggs hatched out from each lot were recorded.

**Parasitization of *C. blackburni* to *H. armigera* eggs**:

The parasitization by *C. blackburni* was studied by exposing 100 eggs of *H. armigera* to adult parasitoids in five repeats. The parasitized egg-sheet was replaced at 48 h interval by fresh unparasitized eggs up to 8-9 days of the adult parasitoids life period for oviposition. The parasitized egg-sheets were then transferred to labelled plastic jars containing sufficient quantity of AD. The number of adults parasitoids emerged were counted from each jar. To study the parasitization by *C. blackburni on H. armigera*, the parasitoid and host eggs were maintained at a ratio of 1:100, 2:100, 3:100, 4:100 and 5:100 with four replications. The observation on per cent parasitization was recorded after the egg incubation period.

**Development of *C. blackburni* on *H. armigera***:

Developmental period recorded to complete one generation from egg to adult for host and parasitoid.
Mass production of host insects:

Potato tuber moth *Phthorimaea opercuella* (Zeller):  

The host insect, *Phthorimaea opercuella* was mass reared in laboratory for obtaining sufficient number of eggs for mass production of *C. blackburni*. The initial culture of *Phthorimaea opercuella* as an egg sheet was obtained from the Biological Control Laboratory of Agricultural Entomology Section, College of Agriculture, Pune. Mass rearing of Potato tuber moth (PTM) was undertaken on stored potato throughout the experimental period in the laboratory.

For mass rearing of PTM, medium sized potatoes were selected were cleaned with duster cloth. The cleaned tubers were first nailed by rolling them on a puncturing brush (100 nails/ 1.25 sq cm) (Planter and Oatman., 1972). The punctured potato were placed in rearing plastic basket over a layer of already sterilized coarsely sieved soil of about 1.5 cm thickness allowing 1.0 to 1.5 cm clearance between tubers. An egg – sheet was placed on the top of the freshly punctured potato with the eggs side down (Platner and Oatman, 1972). The eggs used for infesting the tubers were about to hatch within a day. Each rearing basket containing potato was held for larval feeding up to 15 days from the time, the eggs hatched and the larvae entered the potatoes. The eggs hatching takes place at 26±2°C temperature. This procedure allowed the larvae sufficient time to develop up to maturity and approximately 10 to 12 days they fed in the tuber before emerging to pupae. After 15 days, the expended potatoes were discarded. Most of the larvae pupated in soil by attaching themselves to bottom of the basket with a flat piece of sheet metal and poured on a woven wire sieve to separate the excess soil from the pupae (Anonymous, 1996; 2000; Gomma et al. 1980).
The pupae were held in a wide mouth jar for 4 to 6 days as provided enough time for all the months to emerge. The moths were collected daily and kept in an oviposition glass jar covered with muslin cloths. The moths were provided with 20% honey solution soaked in a cotton swab. After mating, females oviposited on the underside of the muslin cloth on the top which has been placed on several 0.5 cm thick slices of potato to serve as an attachment. New moths were added in oviposition jar and collect egg-sheet daily.

**Production of *C. blackburni* on PTM:**

Potatoes (0.5 kg) were taken in each plastic bowl and such six separate lots were maintained for experimentation. The egg sheets of PTM each were having 100-600 eggs in different bowls on duly punctured potatoes. The larvae hatching from PTM eggs were future reared till formation on of pupae and emergence of moths (Kroschel and Koch, 1994). The observations on number of pupae and/or adults emerged were recorded.

**Hatching percentage of PTM eggs:**

Freshly laid eggs (100 eggs) by gravid females were maintained in five different lots separately and numbers of eggs hatched out from each lot were recorded. The number of eggs released in different bowls containing 0.5 kg food media of potato as in aspect I above which gave maximum number of moth emergence was taken into account for computation of food requirement of PTM larvae. The quantity of potato required for rearing the hatched out larvae were estimated by considering hatching percentage of PTM eggs.
Parasitization in PTM eggs by *C. blackburni*:

The parasitization by *C. blackburni* was determined by exposing 100 eggs of PTM to 1 parasitoid in five repeats. The egg sheets were replaced after every 48 h and fresh unparasitized one day old eggs of PTM were provided up to 8-9 days life of the adult parasitoid for oviposition. The parasitized eggs were then transfer to labelled plastic bowls containing duly punctured potatoes. The number of adult Parasitoids emerged were counted from each bowl (Ballal, 1991). Developmental time of *C. blackburni* on PTM egg to adult was recorded for five generation.

**Developmental period of *C. blackburni* on PTM eggs:**

Developmental period of egg to adult was recorded for host and parasitoid for five generations.

**Mass production of Rice Moth, *Corcyra cephalonica stainton***:

The initial culture of *C. cephalonica* was obtained from the National Bureau of Agriculturally Important Insects (ICAR), Bangalore and mass multiplied in the lab. A good quality wheat grains used for consumption were taken and milled coarsely to make 3-4 pieces of each grain. These grains were treated with 0.1 % formalin spray to avoid development of mould and also retain moisture to the extent of 15-16%. These gains were air dried to remove traces of formaline. The rearing of Corcyra was undertaken in wooden boxes of 45x30x15 cm size with well fitted lid having four holes (2 cm diameter) at equidistance closed with fine wire mesh for aeration. Each Corcyra rearing box was filled with 2.5 kg crushed wheat grains and inoculated with 0.5 cc eggs of Corcyra. The yeast powder of 2 g per 2.5 kg crushed grains was added in each rearing boxes to enhance
the nutritive value of the food material. These boxes were kept undisturbed for about 30
days at 27 ± 2°C temperatures and 70 ± 5% relative humidity for ideal development of
larval and pupal stages of Corcyra. The moths emerged from pupae in the rearing boxes
were collected with the help of aspirator. These moths were the transferred to oviposition
cage (20x20x20 cm) fitted with 20 mesh wire sieve at bottom for egg laying which was
placed on rectangular funnel shaped iron stand. A glass beaker (100 ml) was kept below
the funnel for egg collection. The eggs were collected daily. Newly collected moths were
replaced by dead ones in the oviposition cage. From the harvested eggs, one third
quantity of eggs were used for reculturing the host insect and remaining were used for
mass culturing of the parasitoid C. blackburni.

**Production of C. blackburni on Corcyra Cephalonica**

Crushed wheat grains (200 gm) were taken in each plastic bowl and such six separate lots
were maintained for experiments. Based on the results of pilot reading and earlier reports,
about 1 cc eggs (1 cc eggs =18,000 eggs) of Corcyra pasted on card (egg card) was
parasitized with 400 adults of C. blackburni. Then the parasitized egg card of Corcyra cut
into small bits. Each bits having 100 to 500 eggs were released in different bowls
containing crushed wheat grains which were further reared till formation of pupae and
emergence of Corcyra moths as well as adults of C. blackburni (EL-Buzz et al.1979). The
observations on number of adults of C. cephalonica and C. blackburni emerged were
recorded.
Hatching percentage of *C. cephalonica* eggs:

Total 100 fresh eggs in five different lots were maintained separately and numbers of eggs hatched out from each lot were recorded.

Parasitization in *C. cephalonica* eggs by *C. blackburni*:

The parasitization by *C. blackburni* was carried out by exposing 100 eggs of Corcyra to one adult parasitoid in five repeats. The parasitized egg-card was replaced at 48 h interval by fresh unparasitized eggs up to 8-9 days of the adult parasitoids life period for oviposition. The parasitized egg cards were then transferred to labelled plastic bowls containing crushed wheat grains. The number of adult parasitoids emerged were counted from each bowl (Anonymous, 2000; Manoharan, 1982).

Developmental period of *C. blackburni* on *C. cephalonica*:

Developmental period of egg to adult was recorded for host and parasitoid for five generations.

2.2.6. Mass production of an egg-larval parasitoid *C. blackburni* Cameron (Braconidae: Hymenoptera):

A nucleus culture *C. blackburni* was obtained from Biological Control Laboratory of Agriculture Entomology Section, College of Agriculture, Pune and National Bureau of Agriculturally Important Insects (ICAR), Bangalore. Mass rearing of the parasitoid was carried out at 27 ±1°C temperature and 65±5 % relative humidity.

This parasitoid was mass reared on PTM. The egg sheet of PTM each containing 1000-1500 eggs was obtained and each egg sheet was stapled on a thick drawing sheet (20x15
cm). In each jar eggs sheet were placed in slanting position for facilitating easy exposure of all eggs to the parasitoids for parasitization. The newly emerged adult parasitoids were released in the oviposition jar in a parasitoid: host ration of 1:50 being ideal for obtaining the maximum percentages progeny production from one day old eggs. The parasitoid in oviposition jar provided with 50% honey solution in cotton swab. A PTM eggs were kept for parasitization for 2 days then these egg sheet were replaced by another such two eggs sheet. The parasitoid egg- sheet was put over layer of punctured healthy uninfested tubers with egg side down. The parasitized larvae hatched out from the eggs and infest tubers. The infested tubers were then placed in another basket already provided with a layer of coarsely sieved sterilized soil at bottom for pupation and the top with fine wire mesh. After three weeks, the totally expended potatoes were discarded and earthen pupae were separated by sieving the soil. Thus, the silvery white pupae of *C. blackburni* were collected and kept in a glass tube plugged with cotton. The parasitoid took 26±1.5 days to complete its development in eggs as well as larvae of PTM and emerged from the pupae.

1.3 Results

**Rearing of Helicoverpa armigera larvae in the laboratory:**

The parasitoid *C. blackburni* parasitizes *H. armigera*. This insect is amenable to undertaken mass production on semi synthetic artificial diet under laboratory conditions throughout the year. Hence the attempt was made to mass rear the parasitoid using *H. armigera* as host insect.
**Hatching percentage of H. armigera:**

In this laboratory experiment, total 500 eggs obtained from healthy pairs of *H. armigera* kept separately in five different lots which were observed daily for hatching and data are presented in Table 1. Out of 500 eggs, 443 were hatched out. Thus the hatching was 88.6%.

**Table No. 2.3.2 Hatching percentage of H. armigera**

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>No. of eggs/lot</th>
<th>Moth</th>
<th>Percent hatching</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>500</strong></td>
<td><strong>443</strong></td>
<td><strong>88.6</strong></td>
</tr>
</tbody>
</table>

**Parasitization of C. blackburni to H. armigera eggs:**

The parasitization by *C. blackburni* was studied by exposing 100 eggs of *H. armigera* to one to five adults of parasitoids *C. blackburni* in five repeats.

The data from Table 2.3.3 showed that out of 100 eggs of *H. armigera* provided for parasitism to five adults of *C. blackburni* (5 adults /100 eggs), 325 adults of *C. blackburni* were emerged. Thus parasitism was worked out to 65%. For getting more
number of parasitoids, five adults of *C. blackburni* can use for parasitized 100 eggs of *H. armigera*.

**Table No. 2.3.3. Parasitization of *C. blackburni* to *H. armigera* eggs:**

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>No. of eggs/lot</th>
<th>No. of parasitized released/lot</th>
<th>No. of adults parasitoids emerged/lot</th>
<th>Parasitism (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>1</td>
<td>35.5</td>
<td>35.5±1.81</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>2</td>
<td>40.4</td>
<td>40.4±1.51</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>3</td>
<td>54.2</td>
<td>54.2±4.02</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>4</td>
<td>60</td>
<td>60±2.23</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>5</td>
<td>65</td>
<td>65±4.24</td>
</tr>
</tbody>
</table>

**Figure 1. Parasitization of *C. blackburni* in *H. armigera***
Developmental period of *C. blackburni* on *H. armigera*:

Developmental time recorded to complete one generation from egg to adult for host and parasitoid. 33.5 ± 1.9 and for parasitoid it was 28.6 ± 2.8.

Mass production of *C. blackburni* on *P. opeculella* (PTM) (Zeller):

The egg- larval parasitoid, *C. blackburni* was mass reared in the laboratory using different host insects viz. PTM, *C. cephalonica*.

Production of *C. blackburni* on PTM:

Table No. 4.2.1 shows that the number of pupae ranged from 70 to 127 and moths emerged ranged from 56 to 108 were developed when 100 to 600 eggs of PTM were released on 0.5 kg potato. The maximum pupae (175) and moths (155) were received from the bowl of where in 500 eggs of PTM were released in 0.5kg of potatoes.

Table No. 2.3.5.1. Production of *C. blackburni* on PTM:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>No. of eggs released per bowl (0.5kg potato)</th>
<th>No. of pupae collected</th>
<th>No. of moths emerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>70</td>
<td>76</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>60</td>
<td>46</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>100</td>
<td>81</td>
</tr>
<tr>
<td>4</td>
<td>400</td>
<td>153</td>
<td>84</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>175</td>
<td>155</td>
</tr>
<tr>
<td>6</td>
<td>600</td>
<td>127</td>
<td>108</td>
</tr>
</tbody>
</table>

2.3.5.2. Hatching percentage of PTM eggs:

The results indicated that out of 500 eggs 445 eggs of PMT were hatched out and the hatching was 89.00 percent.
Table No. 2.3.5.2 Hatching percentage of PTM eggs:

<table>
<thead>
<tr>
<th>Lot No</th>
<th>No. of eggs/lot</th>
<th>No. of eggs hatched out/lot</th>
<th>Percent hatching</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>500</td>
<td>445</td>
<td>89.0</td>
</tr>
</tbody>
</table>

2.3.5.3. Parasitization in PTM eggs by *C. blackburni*:

The data showed that out of 500 eggs of PTM provided for parasitization to *C. blackburni* adults, the eggs were parasitized and 384 pupae of the parasitoid received and thus the parasitism was worked out to 79.4%.

Table No. 2.3.5.3 Parasitization in PTM eggs by *C. blackburni*:

<table>
<thead>
<tr>
<th>Lot No</th>
<th>No. of PTM eggs/lot</th>
<th>No. of parasitoid released/lot</th>
<th>No. of pupae of the parasitoid received</th>
<th>No. of adults parasitoids emerged</th>
<th>Parasitism (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>1</td>
<td>80</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>1</td>
<td>78</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>1</td>
<td>81</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>1</td>
<td>79</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>1</td>
<td>79</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>500</td>
<td>5</td>
<td>397</td>
<td>301</td>
<td>79.4</td>
</tr>
</tbody>
</table>

Percent adult parasitoid emergence from pupae = 75.81
Developmental period of *C. blackburni* on PTM eggs:

Developmental period recorded to complete one generation from egg to adult for host 25.5 ± 2.1 and for parasitoid it was 26.7 ± 1.5 days.

Mass production of *C. blackburni* on *C. cephalonica*:

The parasitoid, *C. blackburni* accepts the factitious host, *C. cephalonica* and parasitizes its eggs under laboratory condition. Therefore, an attempt of mass culturing of *C. cephalonica* was made for the production of *C. blackburni*

Table No. 2.3.6.1 Production of *C. blackburni* on *C. cephalonica*:

*C. cephalonica* is factitious host of *C. blackburni* and parasitizes the host eggs under laboratory conditions but the developmental period of parasitoid egg as well as larval stages *C. cephalonica* found prolong upto 43.5 ± 3.5. Moreover it was difficult to sort out the pupae of the parasitoid from the thick crust of crushed wheat grains. On the basis of pilot trial and reports of earlier workers (Anonymous, 2000), and adults of *C. blackburni* found to parasitize 70 to 100 eggs of *C. cephalonica* pasted on egg-card. From the present study for the production of the host insect and the parasitoid showed maximum moths of *C. cephalonica* and *C. blackburni* from the jar containing 200gm crushed wheat grains inoculated with 500 and 600 eggs respectively.
Table No. 2.3.6.1 Production of *C. blackburni* on *C. cephalonica*:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>No. of eggs released per bowl (0.5kg potato)</th>
<th>Quantity of crushed Wheat grains (g)</th>
<th>No. of Corcyra moths emerged</th>
<th>No. of adults of <em>C. blackburni</em> emerged</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>200</td>
<td>25</td>
<td>47</td>
<td>72</td>
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<tr>
<td>2</td>
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<td>200</td>
<td>77</td>
<td>91</td>
<td>168</td>
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<tr>
<td>3</td>
<td>300</td>
<td>200</td>
<td>60</td>
<td>169</td>
<td>229</td>
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<tr>
<td>4</td>
<td>400</td>
<td>200</td>
<td>80</td>
<td>81</td>
<td>161</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>200</td>
<td>75</td>
<td>143</td>
<td>218</td>
</tr>
<tr>
<td>6</td>
<td>600</td>
<td>200</td>
<td>155</td>
<td>68</td>
<td>223</td>
</tr>
</tbody>
</table>

2.3.6.2. Hatching percentage of *C. cephalonica*:

For finding out hatching percentage of *C. cephalonica*, total 500 eggs were kept in five different lots each with 100 eggs and numbers of eggs hatched out per lot were counted. The data recorded daily and are presented in table. Out of 500 eggs, 420 eggs were hatched out and the hatching was 84%.

Table No. 2.3.6.2. Hatching percentage of *C. cephalonica*:

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>No. of eggs/lot</th>
<th>No. of eggs hatched /lot</th>
<th>Percent hatching</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>500</td>
<td>420</td>
<td>84</td>
</tr>
</tbody>
</table>
2.3.6.3. Parasitization on *C. cephalonica* eggs by *C. blackburni*:

The data showed that out of 500 eggs of Corcyra provided for parasitism to *C. blackburni* adults, 328 adults of *C. blackburni* were emerged and thus, the parasitism was worked out to 65.6 percent.

**Table No. 2.3.6.3. Parasitization in Corcyra eggs by *C. blackburni***:

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>No. of Corcyra eggs/lot</th>
<th>No. of adult parasitoids emerged</th>
<th>Percent parasitism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>500</strong></td>
<td><strong>328</strong></td>
<td><strong>65.6</strong></td>
</tr>
</tbody>
</table>

2.3.6.4. Developmental period of *C. blackburni* on *C. cephalonica* eggs:

Developmental time recorded to complete one generation from egg to adult for host 53.5 ± 2.1 and for parasitoid it was 43.5 ± 3.5 days.
2.3.7. Comparison of production of *C. blackburni* on PTM and *C. cephalonica*:

![Graph comparing production of *C. blackburni* on PTM and *C. cephalonica*]

**Figure 2 Production of *C. blackburni* on PTM & *C. cephalonica***

From 300 parasitized eggs of *C. cephalonica* gives maximum numbers of *C. blackburni* adults with compare to PTM, but for 500 eggs, *C. cephalonica* gives less number of parasitoid adults PTM.

![Graph showing hatching percentages of *C. blackburni* on PTM and *C. cephalonica*]

**Figure 3. Hatching percentages of *C. blackburni* on PTM and *C. cephalonica***

Hatching percentage of PTM shows 89% which is a maximum than *C. cephalonica* (84%).

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2.3.8. Comparison of parasitism of \textit{C. blackburni} on PTM and \textit{C. cephalonica}:

![Parasitism Graph]

Figure 4. Parasitization in PTM & Corcyra eggs by \textit{C. blackburni}

The percent parasitism by \textit{C. blackburni} on PTM eggs is 65.6 \% and on \textit{C. cephalonica} is 79.4.

2.3.9. Comparison of developmental period of \textit{C. blackburni} on PTM and \textit{C. cephalonica} eggs:

![Developmental Period Graph]

Figure 5. Developmental period of \textit{C. blackburni} on PTM & \textit{C. cephalonica} eggs

Total development of \textit{C. blackburni} from egg to adult takes $26.7 \pm 1.5$ days on PTM eggs and on \textit{C. cephalonica} parasitoid takes $43.5 \pm 3.5$ days.
1.4 Discussion

The potential of *C. blackburni* has been evaluated against few lepidopteran pests by earlier research workers from parasitization as well as efficiency point of view. This parasitoid showed parasitism on fresh eggs of *H. armigera* laid on leaves of pigeon pea (*Cajanus cajan*) plant (Rangadhamaiiah et al., 1987). Use of *C. blackburni* gave good control of cotton bollworm (Pawar et al., 1986; Thanavendan and S. Jeyarani 2009, Jackson 1979) but super parasitization by *C. blackburni* was highest in eggs of *C. cephalonica* and *P. opercullela* (Rangadhamaiiah et al., 1984). To avoid super parasitisation, the parasitoid host ratio is necessary to study. *C. blackburni* deposited eggs inside the *H. armigera* egg. First and second instars of parasitoid are endoparasitic but 3rd instar is endoparasitic in early developmental stage and ectoparasitic later. Endoparasitic stage feed primarily on hemolymph (Jackson et al., 1979).

To evaluate the efficacy of the parasitoid *C. blackburni* against *H. armigera*, hatching percentage of *H. armigera* and percentage parasitization by *C. blackburni* were studied in laboratory. We found hatching percentage of *H. armigera* was 88% and parasitic potential of *C. blackburni* showed that the highest parasitization of 65% was recorded against *H. armigera*, respectively at a parasitoid host ratio of 5:100 (Table No.4.1.2). In agreement with the results of the present study, Rangadhamaiiah et al., (1987) reported 50% parasitization against *H. armigera* by *C. blackburni*. By release of single parasitoid not have the expected result but by using parasitoid host ratio of 5:100 gave maximum number of percentage parasitization for control of *H. armigera*.

Production and timely availability of *C. blackburni* are the major constraints for application of this parasitoid in fields. Requirement of huge amount parasitoid to control
pests is also one of the major limitations. Hence their mass production is an important aspect in biological control programme. Rearing of beneficial insects in the laboratory in optimum conditions is obligate option.

In the present study, mass production of *C. blackburni* in laboratory is successfully carried out on *Phthorimaea opercuella* (PTM) (Zeller) and *Corcyra cephalonica* Stainton. Also we found most suitable host for rearing of parasitoids *C. blackburni*. The results obtained maximum number of parasitoid adults emerged was recorded at the density of 500 eggs of PTM (Table 4.2.1). 155 adults of *C. blackburni* were obtained from 500 PTM eggs but for same number of eggs of *C. cephalonica* gave 143 parasitoid adults which was less than parasitoid emerged from PTM but we found that for 300 eggs of *C. cephalonica* maximum number of parasitoid adults was emerged which was 169.

Ballal and Kumar (1991) reported response of *C. blackburni* to different densities of eggs of PTM for maximum production and Sarkate et al (1978) and Swamiappan and Balasubramanian (1990) had successfully mass multiplied of *C. blackburni* by using *C. cephalonica*. For mass production of host insects, PTM adults showed more hatching percentage than *C. cephalonica* which was 89%. The percent parasitism by *C. blackburni* in PTM eggs was recorded 79.4% and 65% in *C. cephalonica* eggs. Choudhari et al. (1983) recorded 70% parasitism by *C. blackburni* on potato foliage and used for the control of PTM and Verma and Mangat (1984) observed 60% parasitism in *C. cephalonica* eggs when exposed to *C. blackburni*.

Developmental period of parasitoid from egg to adult was found to be influenced by the developmental period of host. We found significant differences among the development periods of host and developmental period of parasitoid. Number of parasitoid adult
emerged was considered as the number of egg parasitized (Kumar et.al, 1990). There were a significance difference among the developmental period of *C. blackburni* on PTM and *C. cephalonica* was observed. The parasitoid successfully completed their development and emerged when the host reached prepupal stage (Ballal and Kumar, 1991). Parasitoid develops much faster in *P. opercullela* when compared with *C. cephalonica* as host. From laboratory study, percentages of hatching and parasitism and developmental period of both host *P. opercullela* (PTM) and *C. cephalonica*, *P. opercullela* found more conveniently advantageous and suitable to mass breed of *C. blackburni* under laboratory conditions.
1.5 References


