ECONOMIC REARING OF *CHRYSOPERLA CARNEA* (STEPHENS) (NEUROPTERA: CHRYSOPIDAE) IN INSECTARY

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ABSTRACT:- Cost analysis is considered as a valuable tool in monitoring the past decisions and demonstrating the worth of the system. The goal of a mass production programme is to produce the maximum number of quality insects with minimum labour and cost. The maintenance cost of 100 *Chrysoperla carnea* adults was Rs. 192.38 per month, which included the labour cost of Rs. 152.38 and diet cost of Rs. 40. Approximately 4000 eggs per month were obtained from the *C. carnea* adult culture and the cost per egg was Rs. 0.04. This study also revealed that the diet consumption of 100 *C. carnea* larvae was 3.617g of *Sitotroga cerealella* eggs and 1.793g of *Phenacoccus solenopsis* crawlers. Adult emergence rate was significantly higher when provided with *S. cerealella* eggs, which was more economical than that of *P. solenopsis* crawlers. For efficient and quality production of *C. carnea* in laboratory using available and inexpensive equipment to produce the healthy surplus of this predator for experiment and small holding field releases, *S. cereallela* is recommended as more efficient and economic host as compared to *P. solenopsis*.

Key Words: Chrysoperla carnea; Sitotroga cerealella; Phenacoccus solenopsis; Biological Control; Cost Effective Rearing; Economics; Pakistan.

INTRODUCTION

Common green lacewings, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae), is general predators, and very efficient and useful biological control agent (Sattar and Abro, 2011). They are successful predators of jassids, whiteflies, thrips, aphids and mites (Singh and Manoj, 2000; Zaki and Gesraha, 2001; Venkatesan et al., 2002). They also feed on the eggs and tiny larvae of the cotton bollworms (Ahmad et al., 2003). Larvae of *C. carnea* are voracious and efficient biological control agents. It is their excellent predatory potential on other soft bodied insect pests of crops, which suppresses the insect pests' density below the economic injury level (McEwen et al., 1999).

Green lacewing larvae are effective for inundative biological control of several pests of greenhouse and field crops (Harbaugh and Mattson, 1973; Sattar et al., 2007). They have short life cycle and a vast diversity of host; and can easily be mass reared

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(Sattar et al., 2007; Wihtcomb, 1964; Ridgway et al., 1970), search efficiently and resist some pesticides (Sattar and Abro, 2011). However, the commercialization of natural enemies such as *C. carnea* and their increased use in pest management requires reducing the cost of their mass-rearing and improving the success rate. To start a biological control programme, production and quality maintenance cost and labour estimation is essential for the mass rearing of natural enemies (Larock and Ellington, 1996).

Mass rearing of predators or any biological control agent is a prerequisite for any successful biological control programme, but it is impossible without using a standard host. This study was carried out to find out cost-effective technologies for rearing and mass production of *C. carnea* in laboratory. Its main target was to develop a cost effective mass rearing technique for obtaining maximum number of good quality *C. carnea* with minimum labour and cost for releases in the field to control the insect pests.

MATERIALS AND METHOD

This study was carried out in the Insectary-Biological Control Laboratories, National Agricultural Research Centre (NARC), Islamabad, Pakistan, under controlled laboratory conditions i.e., 26 ± 2°C and 65 ± 5 % relative humidity.

Hosts Rearing

For current study two hosts, i.e., angoumois grain moth, *Sitotroga cerealella* (Oliver) eggs and pink hibiscus cotton mealy bug, *Phenacoccus solenopsis* (Tinsley) crawlers, were used. To obtain *S. cerealella* eggs following procedure was adopted. Adults of *S. cerealella* from adult rearing chambers were collected in oviposition jars. These jars were then placed on a plate having starch for oviposition. This starch was then passed through 80 mesh sieve to separate the eggs from starch. These eggs were provided to the larvae of *C. carnea*.

Adults of *P. solenopsis* were collected from cotton fields of NARC, Islamabad. *P. solenopsis* was reared in wooden rearing cage (45cm × 45cm × 30cm). The top and walls of cage were fixed with black muslin cloth. Mealy bugs were provided with bottle gourd fruit for feeding and offspring production. The crawlers were collected from the bottle gourd with fine camel hair brush (No.1) for being provided to the *C. carnea* larvae. A Diamond MCT-500 (Ohaus Corporation, Pine Brook, New Jersey, USA) scale with 0.0001g accuracy was used for weighing *S. cerealella* eggs and *P. solenopsis* crawlers.

Rearing of *C. carnea* Adults

Adults of *C. carnea* were collected from wheat fields of NARC, Islamabad and mixed sex (approximately 1:1) were placed in plastic cage (35cm × 20cm × 20cm), covered with a plastic lid, for maintaining the culture. A sheet of black paper stretched across the top of the cage, acted as an oviposition substrate. Holes were present in the cage for good ventilation. These adults were fed on semisolid artificial diet comprising yeast, honey, sugar and water (1:1:1:4). The diet was pasted on plastic strips placed horizontally in adult rearing cage. Wet soaked cotton in Petri dish was placed inside the cage to provide moisture inside following Ashfaq et al. (2004). Fresh diet was replaced on alternate days for the adults following McEwen et al. (1999). Eggs laid on black sheet by females were collected on alternate days with razor. Proper sanitation of cage was ensured (Ashfaq et al., 2004).

Cost Analysis of *C. carnea* Mass Production

For the evaluation of rearing cost, 100 fresh eggs of *C. carnea* were placed individually in 100 plastic vials with the help of a fine camel hair brush to avoid cannibalism (Gautam, 1994). Freshly laid eggs of *S. cerealella* after weighing to a specific quantity, were placed in each vial as larval diet. These eggs were placed in freezer to delay the hatching. Diet for *S. cerealella* treatments was provided three times during larval period for each set of replications until the cocoon formation. Newly emerged adults were placed in chimney glass. After three days of emergence, adults were identified as male and female. Same procedure was adopted for the diet placement of mealy bug crawlers but this time diet was replaced on alternate days because of the mortality of mealy bug crawlers without their host. Three replications for each treatment were made and data on cost of purchased items and handling time (time required for egg harvesting, food supply and sanitation of cages and larval diet placement time etc.) was recorded carefully.

RESULTS AND DISCUSSION

Cost Analysis

The adopted technique was intended for small scale production of lacewings. The initial estimated recurring cost to run this set up was Rs. 900. Total cost and the number of items were ascertained (Table 1).

Table 1. Initial purchase cost for production of 100 *C. carnea* adults

Item	Cost (Rs.)
Jars	200
Plastic vials	400
Cutter	30
Black glaze sheet	20
Adult cage	200
Camel hair brush	50
Total cost	900

Cost of Rearing Stock Culture

The cost for the adult culture maintenance i.e., adult diet placement time, egg harvesting time and adult cage sanitation time was calculated on monthly basis. Labour time consumed for adult culture maintenance was calculated as

Table 2. Stock culture maintenance cost of 100 *C. carnea* adults for one month

Parameter	Time (min)	Cost (Rs.)
Adult diet placement time	24.75	-
Egg harvesting time	90.30	-
Adult cage sanitation time	6.86	-
Total labour time	121.91	-
Labour cost	-	152.38
Cost of adult diet items	-	40.00
Total labour cost	-	192.38
Cost/egg	-	0.04

121.91 minutes (Table 2). Labour cost was calculated as Rs. 152.38 and adult diet cost was estimated to Rs. 40 (Table 2). So total cost for adult culture maintenance was calculated as sum of labour cost and adult diet cost, which was Rs. 192.38 (Table 2). As a result of this adopted technique approximately 4000 eggs per month were obtained, which was an additional output. The cost of egg was calculated by adult culture maintenance cost divided by number of eggs produced, which was Rs. 0.04 (Table 2).

Cost Analysis for Production of 100 Adults /Generation

Amount of the diet consumed by 100 larvae of *C. carnea* was 3.617g of *S. cerealella* eggs and 1.793g of mealy bug crawlers (Table 3). Total average labour time from egg to adult emergence of *C. carnea* was 57.6 min on *S. cerealella* and 46.35 min on *P. solenopsis* (Table 3). Labour time included egg and larval diet placement, larval diet collection and pupal collection. The estimated labour cost was Rs. 72 on *S. cerealella* and Rs. 58 on *P. solenopsis* (Table 3). Labour cost was calculated by time multiplied by the per hour salary (Rs.75) of a daily paid labour at NARC, Islamabad. Total cost per generation was calculated by total labour cost plus larval diet purchase cost. The cost efficiency of the technique was observed on *S. cerealella* eggs (76 adults) as compared to mealy bug crawlers (56 adults) (Table 3). Cost of producing one *C. carnea* adult was lower on *S. cerealella* (Rs. 1.35 / adult) as compared to *P. solenopsis* as host (Rs. 1.84 / adult) and this difference was largely due to the increased adult emergence on *S. cerealella* eggs (Table 3). Average cost per adult is obtained as total cost per generation divided by number of adults produced from 100 eggs.

The larval period on both the diets was almost 10 days. Using this technique three generations of *C. carnea* can be produced in a month, i.e., 300 adults per month. By this way the efficiency of the system can

Table 3. Recurring cost for producing 100 *C. carnea* adults/ generation from *S. cerealella* and *P. solenopsis* under laboratory conditions

Parameter	*S. cerealella*	*P. solenopsis*
Estimated time (min)		
Egg and larval diet placement time	34.64	30.44
Larval diet collection time	16.88	9.83
Pupal collection time from vials	6.08	6.08
Total average labour time	57.60	46.35
Estimated cost (Rs.)		
Total labour cost	72.00	58.00
Larval diet purchase cost	30.00	45.00
Total cost/generation	102.00	103.00
No. of adults produced from 100 eggs	76.00	56.00
Average cost/adult	1.35	1.84

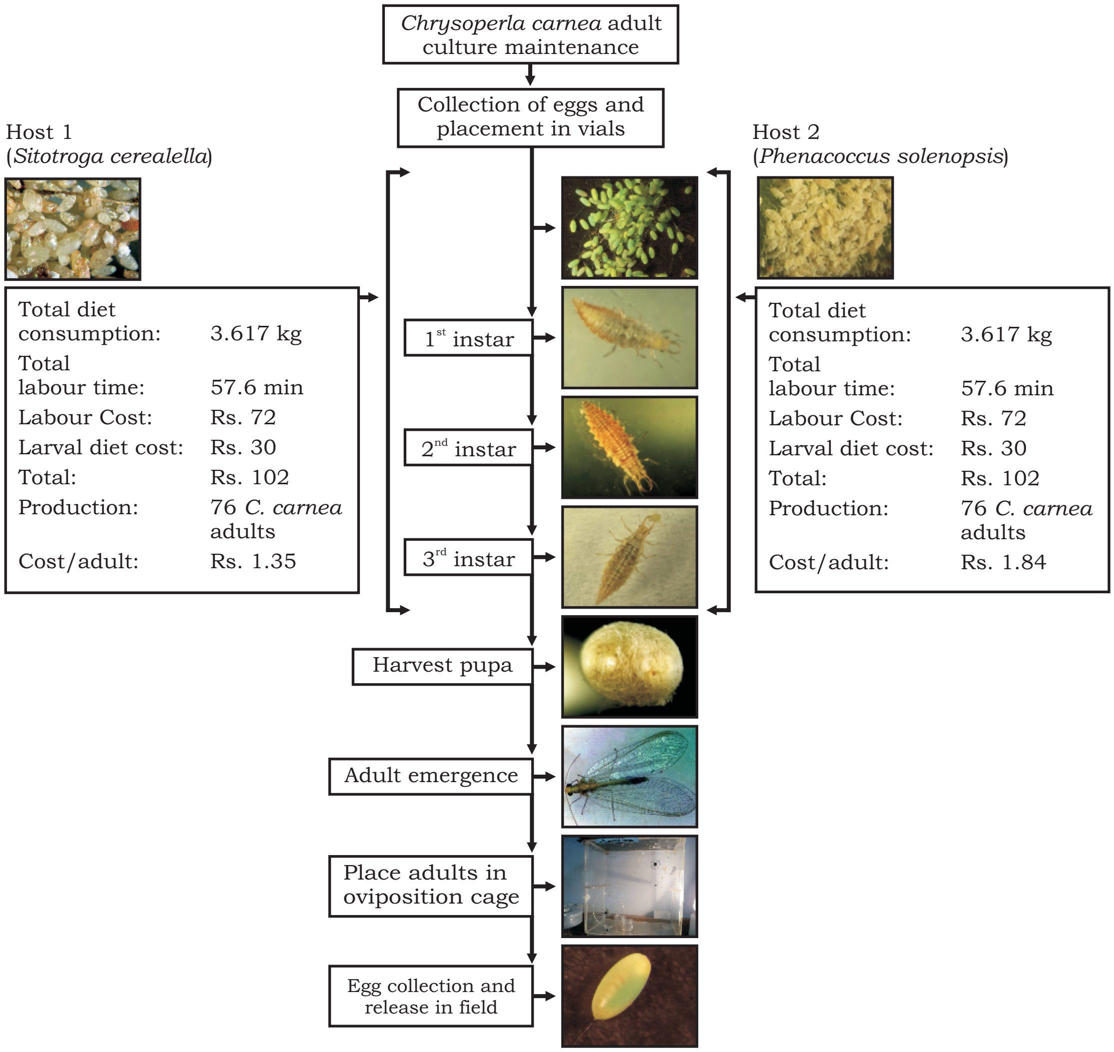

Figure 1. Flow chart of cost analysis for 100 *Chrysoperla carnea* adults reared on *Sitotroga cerealella* eggs and *Phenacoccus solenopsis* crawlers

be enhanced and the associated cost can be minimized.

The economic information gathered identifies the viability of the production technique. Cost analysis can be considered as a valuable tool in demonstrating the worth of the production system (McEwen et al., 1999). Biological control agents are easier and quicker to distribute than the application of pesticides and can potentially be a cheaper control method in field conditions (Chakraborty and Korat, 2010; Nordlund et al., 2001).

For beneficial insects like *C. carnea*, rearing costs have not been published presumably due to commercial sensitivity (Greer, 1993). The main advantage of this study is that it has provided useful information about the costs associated with both the hosts provided to the larvae for assessment of labour input and use of hosts and materials.

Greer (1993) mentioned that cost benefit analysis allows the comparison of scientific projects in terms of cost, returns, time and success. The results achieved from the mass rearing system development for *C. carnea* indicated that the highest efficiency was found on *S. cerealella* eggs as compared to the mealy bug. Analysis has also shown a clear difference about inputs such as purchased material cost and labour, which was higher on mealy bug than *S. cerealella* eggs. Labour costs were dramatically reduced on the *S. cerealella* eggs and from production point of view this larval host was most economic and efficient. A trend emerged indicating that the total cost of adults declined over generation produced by *S. cerealella* eggs. The main explanation for this decline is that by the end of the experiment, time spent on handling predators, prey and host rearing declined as in this host selection.

The total initial purchase cost was made up of the costs which are fixed. The variable costs, sometimes referred to as direct costs, are the expenses directly related to production (cost for adults to produce stock culture and cost of handling 100 larvae per generation). Horsman (1988) indicated that if demand for a product grows, it can be achieved through the average cost and output. The average cost was obtained simply by dividing total cost by output. There is a considerable potential for large number of adults to emerge, survive and reproduce. Based on the results achieved from this rearing system, more number of adults emerged from the *S. cerealella* eggs and less on *P. solenopsis*.

It is concluded that for efficient and quality production of *C. carnea* in laboratory using available and inexpensive equipment to produce the healthy surplus of this predator for experiment and small holding field releases, *S. cereallela* eggs are recommended as more efficient and economic host as compared to *P. solenopsis* crawlers (Figure 1).

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