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Dependence of rearing and development of lacewing (*Chrysopa phyllochroma* Wesmael. 1841) on the types of diet

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Abstract
Within the framework of our study on biological method for controlling harmful insects, we aimed to investigate the types of diets for predator lacewing of *Chrysopidae* family in order to rear this insect under laboratory condition and choose both preys and artificial diet suitable for them. To archive the goal, such objectives as rearing of predator lacewing in laboratory condition, investigating both preys and artificial diets for both adult insects and larva, choosing the most suitable prey or diet and clarifying the effects of diet types on reproduction and development of lacewing were accomplished. Performing experiment to rear lacewing under suitable condition and investigate the diets of both adult lacewing and its larvae and selection of most suitable diet for them are main features of the present study.

Keywords: *chrysopa phyllochroma* wesmael.1841, breeding, prey

1. Introduction

Finney (1948, 1950) initiated the first large scale activities of mass culture of *Chrysopa carnea* from insects of family *Chrysopidae*, while Doutt and Hagen (1949, 1950) [27] carried out pioneering research on net winged/Neoptera insects against pests. When Stiling and Killington (1985) [27] conducted study on the use of lacewing against pests, they examined the use of lacewing to control greenhouse mealybugs. Investigated the potential of the hemerobiid *Micromus variegatus* Fabricius as a predator of mites. In 1960-1970, work was carried out to devise an artificial diet for lacewings (Hagen and Tassan 1970) [27]. During late 1970's the biological controlling methods were being successfully developed, their effects on joint management activities for controlling pests were being reported, and several experiments to make artificial diet for lacewing performed by Nordlund and Morrison (1992) [27] were successful. Mostly, insects belonging to genus *Chrysoperla* are reared and more studies were conducted on *Chrysopa carnea.,* and *Ch.rufilabris (Burmeister)* in Europe and North America and *Ch.sinica* in China [27]. In the Guangdong Institute of entomology, China, the studies on rearing of beneficial predator and parasitic insects were performed, they were highly successful and from 1970 mass culture of lacewings such as *Ch.septempunctata Wesmael., Ch.phyllochroma Wesmael., Ch.formosa Brauer., Ch. boninensis Okamota.,* and *Ch. sinica Tjeder* started to control aphid and red mite of cotton, wheat and pea plants. During this period, eggs of *Corcyra cephalonica* were used for diet of lacewings. Mixture of 500 g rice bran and 150,000 to 200,000 eggs of *Coɛcyɛa cephalonica* was used for rearing *Ch. sinica and Ch.septempunctata* and administered for controlling harmful pests on one third of one ha area. On the basis of above, artificial diet was improved and Li Li-ying developed the ration of artificial diet for feeding both larvae and fully matured lacewings of 9 species belonging to genus *Chrysopa*. Wooden box (40x30x9 cm) covered with neulon and with glass window on its top was used for rearing the larvae. The box was protected from cannibalism and allowed the possibility of pupation and cartoon box was used for feeding matured insects. Then artificial diet started to be produced by use of machinery in China, diets for *Ch. sinica and Ch.septempunctata* were made, these insects were successfully reared, and use of *Ch.sinica* against cotton moth larvae, fruit red mite and greenhouse whitefly and *Ch.septempunctata* against forest and fruit aphid was successful. Also, *Ch.phyllochroma*. *Ch.formosa and Ch.shansiensis* were used. In Henan province, 300,000 to 450,000 eggs and 30,000 to 45,000 larva of lacewings per ha were used against cotton moth larvae in 2 or 3 replicates at 4 or 5 days intervals on 10 ha area from 1974. Number of moth eggs and larva dropped by 80% and 91% respectively at day 7 after the use of lacewings [13]. Problems in compositions of diets have been fully solved, it facilitated breeding of the insect in large numbers, and efforts are now focused on further marketing and utilization. However, it is peculiar that compositions of the diets differ with species of the insect. Introduction of Hydrocapsules in rearing insects resulted in creation of artificial diets useful not only for rearing beneficial insects, but also for killing harmful insects. Hydrocapsules are made by encapsulation technology, the diet particle sizes (from 100 µ to 2 cm) are suited to insect species and the diet contains a range of compounds, including proteins, fat and carbohydrates. Nowadays, production of artificial diets by use of this technology has been fully introduced into practice worldwide and bigger companies such as ARS and Koppert are leading with their production rates. Ulqah (2005) and many other authors conducted the studies on diets of matured lacewings by comparison of artificial diets of 3 kinds with standard diets. Artificial diet includes mostly sugar, milk, honey and eggs. Hill (1989) investigated sugar is an important component in adult diet exerting effects on egg laying, while McEven and Kidd (1995) [27] studied the effects of yeast and sugar lead the egg

production to maximal level, as well as mixture of honey and yeast autolysate exert effects and egg yolk is also an important component of diets. Egg yolk contains greater quanities of saturated, mono unsaturated and poly unsaturated fats, and also vitamins A, B12, E and D, pyridoxine, thiamin, pantothenic acid, riboflavin and niacin (Norioka *et al.* 1984, Rolfes *et al.* 1978). As well, adult lacewing can be fed with yeast lysate (52% protein) and diet mass containing sugar (Morrison, 1985) [27].

2. Materials and methods

The study was performed by use of several conventional methods according to principles of research methodology. These include collection, feeding, rearing, storage, experimentation and estimation of outcomes. The insects were collected by net from vegetable fields and nature during the plant growth period. For feeding lacewing, live insects and artificial diets were used. For above purpose, the experiment of feeding was performed in the following stages: 1.Artificial diets were surveyed and related materials were collected; 2.Artificial diets were selected, prepared and stabilized in laboratory conditions; 3.Larva were fed with both live insects, including plant aphid, mite and beetle larva and artificial diet and 4. Adult insects were fed with honey, pollen and prepared artificial diet.

Preparation of the diet: Diet composition shown in table 2 was used as standard in the present study and diets were rotated daily in the experiment. Diet was prepared once a week and stored in refrigerator till the use. For preparation of artificial diet, all ingredients were steamed (table 2). Meat and liver was grinded, then honey, water, antibiotics, stabilizers, yeast were added and then the mixture was blended. Twenty five ml water in 5 liter laboratory glass beaker was heated to temperature at 90ºC and then 15 g sucrose, 5.0 ml acetic acid and antibiotic were added and mixed thoroughly to solve them. Two preparations were then mixed; egg was then added and mixed with blender for 6 or 7 minutes. Then the diet become softer, smooth and solid, but amorphic.

Table 1: Composition of diet "Kaushalay"

S. No	Composition	Quantity
1	Egg	1
2	Egg yolk	1
3	Honey	30 g
4	Sugar	20 g
5	Yeats extract –dry	30 g
6	Wheat germ	50 g
7	Water	45 ml

Table 2: Composition of artificial diet for green lacewings

Composition	Diet 2
Ground beef	100 g
Bround cattle liver	100 g
Beef powder	-
Cattle liver powder	-
Egg	100 g
Sugar	15 g
Honey	25 g
Bear yeast	12 g
Propionate	0,6 g
Potassium sorbate	0,6 g
Streptomycin sulfate	0,1 g
Chlortetracycline	0,1 g
Agar	-
Distilled water	20 ml
Acetic acid	5,0 ml
Vitiamin solution	10 ml

3. Results of the study

Observation of the impacts of diet types on certain development stage and length of a generation, as well as determination of daily diet intake during the lacewings feeding were done. The term for shifting from larval stage into pupal stage differs depending from the types of diets and the progeny fed with plant aphid underwent pupation for 9 days, which demonstrates type of diets is important for developmental stage of the insect (table 3).

Table 3: Term for shifting from larval to pupal stage depending on diets

S. No	Diets	Term for shifting from larval to pupal stage (date)	Days for shifting from larval to pupal stage
1	Plant mite	09 July- 07 August	28-29
2	Plant aphid	06 August - 15 August	8-9
3	Beetle larva	05 August - 17 August	11-12

Phenological observations on each type of diets for the period of experiment reveal a generation of lacewings lasted 26 to 47 days depending on types of prey and diets (Fig 1).

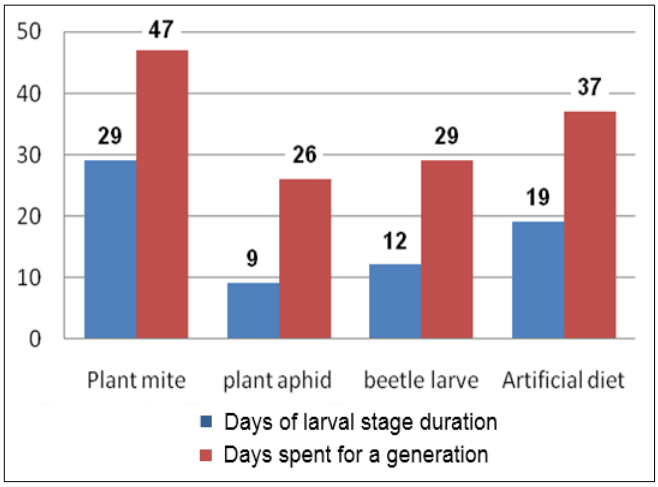

Fig 1: Duration of a generation depending from diet types

To perform the experiment on daily diet intake of larva, 4 individuals from each developmental stages were selected and each larvae of lacewings was fed with 20 lice and 10 beetle larva; 8 lice and 2 beetle larva as a diet of first stage larva, 11 lice and 2 beetle larva as a diet of second stage larva, and 17 lice and 4 beetle larva as a diet of third stage larva were given and it reveals the diet intake increased with larval stages (Fig 2 and 3).

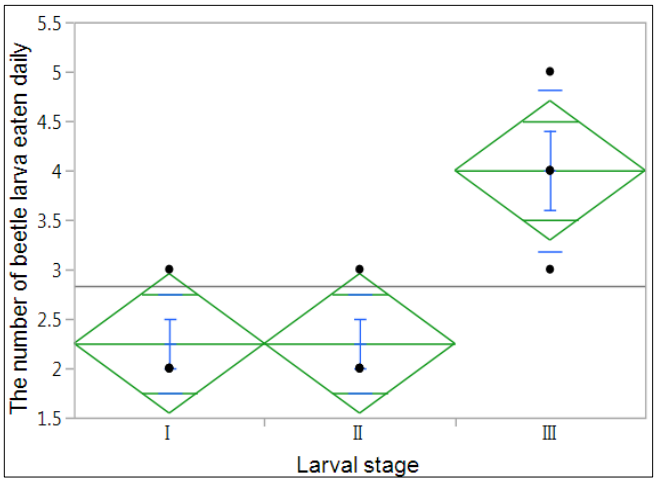

Fig 2: Daily intake of larvae (plant aphid)

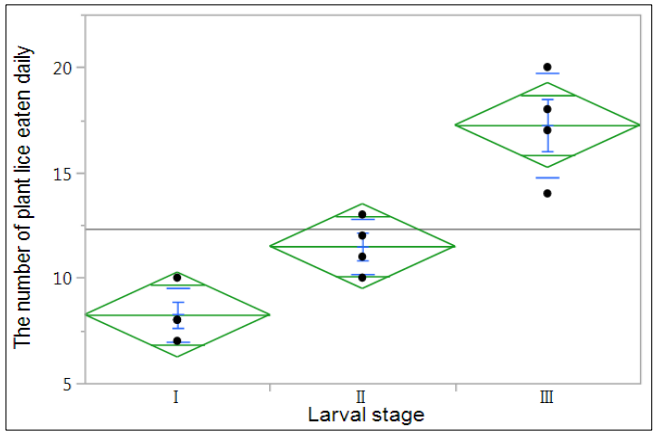

Fig 3: Daily intake of larvae (beetle larva)

Results of the experiments on 4 types of diets for lacewing larva demonstrate the diet made of flour beetle eggs and larva is not suitable for feeding, because more than 70% of the larva fed with flour beetle were died. Therefore, it is seen to be less effective and unsuitable diet. When 4 individuals were selected from each larval stages and each larvae was fed daily with 20 lice, development period of lice each of which was fed with 8 to 17 lire in average is 8 or 9 days, a generation lasts for 25 or 26 days and the results were good, development period of lice each of which was fed with 2 to 4 beetle larva in average is 11 or 12 days, a generation lasts for 28 or 29 days and the results were also good, and development period of lice each of which was fed with plant mite is 28 or 29 days, a generation lasts for 46 or 47 days and the results were fair. Two variants of the insects fed with pollen, two variants fed with Kaushalay diet and honey solution and a variant fed with egg mixture diet for lifespan of adult insect have normal egg production patterns or in average 6 to 8 eggs were laid daily, egg laying lasted for 20 to 30 days and results were good, the first variant fed with pollen had 15 to 20 days period of egg production and laid 3 or 4 eggs and the results were fair or the feed is seen to be useful. Thus, results of all variants of the experiments in adult individuals using 4 types of artificial diets and 6 methods were good. The artificial diet of lacewing larva include beef, liver, sucrose, eggs, distilled water, honey, yeast, acetic acid, dietary stabilizer, propionate, potassium sorbate, streptomycin sulfate, agar, chlortetracycline and vitamin solution. Yeast is added in order to increase egg production of adult females. Diet T2 shown in table 4 was selected as a main diet of the study. However, E compounds and antibiotics for additional storage were not used. The first experiment with 4 variants of artificial diets used during larval stage was ineffective (table 4).

Table 4: Results of the experiment using artificial diet for feeding larva (the first experiment)

Developmental stage	Diet variants		Results
I stage larva	T-1	Horse bone broth gele (yellowish brown, solid, sharp smell)+0.1% sugar+3:1 distilled water	+
	T-2	Meat peptone agar (3%)	+
	T-3	Meat peptone agar (1, 5%)	+
I and III stage larva	T-4	Four times reduced diet	+

Note: + less effective

To prepare above artificial diet, the experiments were repeatedly performed in the forms of diluted, concentrated, capsulated, not capsulated and semi-concentrated, T1 diet was effective and used for feeding larva (Table 5).

Table 5: Results of using artificial diets in larva (second experiment)

S. No	Developmental stage	Diet variants	Results
1	I,II and III stage larva	T1(concentrated)	+++
		T2 (diluted)	+
		T2 (capsulated)	+
		T4 (semi-concentrated)	+

Note: +++ good results
++ poor results and unsuitable diet

For types of diets, feeding with T1 (concentrated) diet led to 17 days development stage and good results, while use of T2 (diluted), T2 (capsulated) and T4 (semi-concentrated) resulted deaths of both first and second stage larva and therefore they are seen as poor or unsuitable diet (table 6).

Table 6: Period of shifting from larval stage into pupal stage

S. No	Diets	Days for shifting from larval stage to pupal stage	Lasted days
1.	T1 (concentrated)	14-31 August	17

Phenological observation on each variants of diets for the period of experiment demonstrates that lacewings in the variant of T1 (concentrated) diet become fully matured after 17 days of pupation and development of a generation lasted 36 days. However, the variants using T2 (diluted), T2 (capsulated) and T4 (semin-concentrated) diets were ineffective. Although the experiments with artificial diets for larva were repeated twice in 2014, they were ineffective. However, the experiments were performed twice in 2015 and diet T1 (concentrated) was effective and used for rearing the insects (table 7).

Table 7: Results of the experiments on diets

S. No	Diet variants	2014				2015			
		Larva	Results	Adult	results	Larva	Results	Adults	Results
1	Variants of artificial diet	4 variants	-	Pollen-2 variant	+ ++	T1 (concentrated) was effective from 4 variants.	+ +	Pollen-2 variants	+ + +
				Kaushalay-diet	++			Kaushalay –diet	+ +
				Honey solution-2 variant	+ + +			Honey solution-2 variants	+ + +
2	Types of prey	1.Flour beetle's *-egg -larvae* 2.Plant aphid	- - +++	-		1.Siberian beetle larva 2. Mite 3. Aphid	+++ ++ + + +	Egg mixture diet	+++

Note: +++ good
++ fair
+poor, unsuitable diet

In the present study, 2 variants of praise and a variant of artificial diet for larva and 4 variants of artificial diets for adult insects alone or experiments using their combinations were selected as proper ones (Table 8).

Table 8: Selection of diets

For larva		For adult insects
Preys	**Artificial diet**	**Artificial diet**
1.Siberian beetle larva	T1 (concentrated) diet	1.Pollen-2 variants
2.Plant aphid		2.Kaushalay –diet
		3.Honey solution-2 varinats
		4. Egg mixture diet
Rearing in the laboratory	Preparation in the laboratory	Combinations and rotational use

4. Discussions

Entomologists A. Tsendsuren and K. Ulykpan reported 10 species of insects belonging to genus *Chrysopa* are distributed in Mongolia [2]. Nattatiee Sirimachan (2005) [24] studied life cycles and mass culture of species *Mallada basalis* of order Neoroptera of family *Chrysopidae* under laboratory condition at temperature 25ºC±2 and 75%±2 humidity and as a result egg production lasted for 43.667±6.506 days and each adult female insect lays 466,333±74.389 eggs, development of larva from first to third stages lasted 2.383±0.515, 2.230±0.439 and 4.444±1.013 days respectively, as a whole it lasts 8.570±0.750 days and pupal stage 9.200±0.447 days. It was also shown that lifespan of adult insect lasts 52.669±13.590 days and period from egg to adult stages lasts 21.42±4.103 days. B.Munkhtsetseg and G.Baigalmaa (2010) [6] reared species *Chrysopa formosa* and *Ch.phyllochroma* in room conditions at temperature 21.9-22°C and humidity 23.5-27.5% and egg development lasts 3 to 5 days, larval development 10 to 15 days and the experiment lasted as a whole for 90 days. As a result, it was demonstrated that lacewing can be reared in laboratory conditions and capable of giving continuous generations, and 584.5 eggs, 499 larvas and 240 pupas in average were obtained for 52 to 60 days. D.Undarmaa and G.Ganchimeg reported feeding *Chrysoperla*

camea with plant lice in the room at temperature 22^0C±2 and lighting at 12:12 ratio resulted in lasting development for 60.5 days, including 7.6 days for egg, 14.5 for larva, 11.3 for pupa and 27.3 for adult stages, while in the variant using wheat and egg diet it lasts 68.3 days, including 9.6 for egg, 17.5 for larva, 12.5 for pupa and 28.5 for adult stages. Among results of the studies by above mentioned authors, those obtained by Patricia S. Silvar (2007) [26] were similar to the results of our study and it reveals not only diets, but also laboratory conditions are important for rearing.

5. Conclusions

1. A total of 398 adult individual lacewings were collected and reared under laboratory condition and as a result 1787 eggs, 1275 larva, 1050 pupa and 722 adult insects were obtained and a total of 328 pupa were used for wintering.
2. As a result of experiments on diets necessary for rearing lacewings, it is demonstrated that 2 types of preys and 1 type of artificial diet are suitable for larva feeding and 4 types of artificial diets are suitable for adult insects.
3. Experiments of diets show larval development lasts for 8 or 9 days in the variant, in which the larva fed with plant mite, whereas it for 17 days and the term for shifting from larval stage into pupal stae depends from diets.
4. Phenological observation of lacewings (*Chrysopa phyllochroma Wesmael.1841*) performed in the laboratory condition (at temperature 28ºC±2 and humidity 60%±2) reveals developments of eggs, larva, pupa and a generation last for 3-4, 9, 14-15 and 24-28 days respectively and sum of effective heat spent for this period was 784ºC.
5. As a result of performing experiment on daily intake for each stages of larva, it is seen that larva in the first, second and third stages feed with 8 lice and 2 beetle larva, 11 lice and 2 beetle larva, and 17 lice and 4 beetle larva respectively per day, and daily intake increased with developmental stages.

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