UNIVERSITI PUTRA MALAYSIA

ARTIFICIAL DIETS AND THEIR EFFECTS ON BIOLOGICAL PERFORMANCE OF GREEN LACEWING, Chrysoperla nipponensis (OKAMOTO) (NEUROPTERA: CHRYSOPIDAE)

SHAFIQUE AHMED

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By

SHAFIQUE AHMED

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

May 2016

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DEDICATION

My Paradise

My Mother

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

ARTIFICIAL DIETS AND THEIR EFFECTS ON BIOLOGICAL PERFORMANCE OF GREEN LACEWING, *Chrysoperla nipponensis* (OKAMOTO) (NEUROPTERA: CHRYSOPIDAE)

By

SHAFIQUE AHMED

May 2016

Chairman : Professor Dzolkhifli Omar, PhD
Faculty : Agriculture

Green lacewings (Neuroptera: Chrysopidae) are the most effective and generalist predators of many soft bodied insects. *Chrysoperla nipponensis*-B (Okamoto) is a recently recorded lacewing in Malaysia and detailed studies on its biological performance are lacking. Moreover, no comparative research has been done on the mass rearing of *C. nipponensis* under laboratory conditions on natural and artificial diets and their effect on its biological performance. Therefore, this study was conducted to evaluate the effects of two types of semi-solid artificial diets and two natural diets i.e., *Aphis craccivora* (Koch) and eggs of *Corcyra cephalonica* (Stainton) on the growth, development and predation of *C. nipponensis* larvae and their potential to be used for the mass rearing of *C. nipponensis*. Composition of artificial diets was same except the addition of whole eggs and ginger in diet-1 and, egg yolk and chemical antimicrobials in diet-2. Results suggested that diet-1 was found to be an alternate to natural diets for the mass rearing of *C. nipponensis*, as larvae reared on diet-1 performed better in terms of larval duration, fecundity and adult longevity as compared to natural diets. However, survival and weight of larvae and pupae was higher when reared on *C. cephalonica* eggs. No difference was recorded between diet-1 and *C. cephalonica* reared larvae in terms of length of 3rd instar larvae, head capsule of 1st and 2nd instar larvae, % adult emergence and their body length. The findings of the life table studies showed that the highest apparent mortality of *C. nipponensis* (37.26%) was observed in immature stages (1st, 2nd, 3rd and pupae) when reared on *C. cephalonica* eggs. The sex ratios (proportion of female to male) in the natural and artificial diets were 0.93:1.00 and 0.87:1.00, respectively. The females reared on artificial diet lived one day longer than those reared on *C. cephalonica* eggs. The maximum life span of females was observed when reared on artificial diet. The maximum oviposition by females reared on *C. cephalonica* eggs was recorded as 10.4 eggs laid on day five, whereas females reared on artificial diet laid a maximum of 9.26 eggs on day nine. The net reproductive rate (Ro) and maximum gross reproductive rate (GRR) of *C. nipponensis* fed on *C. cephalonica* eggs were 69.5 and 223.1 females per female per generation, respectively, while on artificial diet these parameters were 117.24 and 236.89 females per female per generation, respectively. Higher mean generation time (T)

and population doubling time of *C. nipponensis* were 48.16 and 7.00 days observed on artificial diet, respectively. However, intrinsic (r) and finite (λ) rate of increase (females per female per day) of *C. nipponensis* were higher when reared on *C. cephalonica* eggs. Studies on the functional response of 3rd instar *C. nipponensis* larvae reared on artificial diet and *C. cephalonica* eggs showed a type-II functional response to various densities of aphid (*A. craccivora*), mealybug (*Paracoccus marginatus*) (Williams and Granara de Willink) and whitefly (*Bemisia tabacci*) (Gennadius). Based on Holling's disk equation, the highest search rate (á) of larvae (0.68 and 0.40) was observed against mealybug and whitefly when reared on artificial diet and *C. cephalonica* eggs, respectively. Both, artificial diet and *C. cephalonica* eggs reared *C. nipponensis* larvae showed maximum handling time on whiteflies. *Chrysoperla nipponensis* larvae reared on both diets exhibited maximum predation rate on mealybugs with minimum predation recorded on whiteflies. The same R^2 values were recorded for artificial diet and *C. cephalonica* eggs reared larvae against aphids, mealybugs and whiteflies. The newly recorded green lacewing *C. nipponensis* is an important predator in Malaysian agro-ecosystems. *Chrysoperla nipponensis* reared on ginger based artificial diet showed compatible or better performance for various biological and predation parameters, hence can be used for the mass rearing of the predator for the population management of many soft bodied insect pests.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

DIET TIRUAN DAN KESANNYA TERHADAP PRESTASI BIOLOGI GREEN LACEWING, *Chrysoperla nipponensis* (OKAMOTO) (NEUROPTERA: CHRYSOPIDAE)

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Green lacewing merupakan pemangsa yang effektif dan generalis terhadap serangga berbadan lembut. *Chrysoperla nipponensis* direkodkaan ada di Malaysia tetapi kajian terhadap prestasinya masih kurang. Tambahan pula, tiada perbandingan kajian yang dilakukan terhadap ternakan besar-besaran di bawah keadaan makmal pada diet semulajadi dan tiruan dan juga kesan terhadap prestasi lacewing. Oleh itu, kajian ini di jalankan untuk menilai kesan dua jenis diet separa pepejal dan dua jenis diet semulajadi iaitu *Aphis craccivora* dan telur *Corcyra cephalonica* terhadap pertumbuhan,, perkembangan dan kadar pemangsaan larva *C. nipponensis* dan potensi diet ini untuk digunakan dalam ternakan besar-besaran *C. nipponensis*. Komposisi diet tiruan adalah sama kecuali tambahan keseluruhan telur dan halia dalam diet-1 manakala tambahan kuning telur dan bahan kimia perintang antibiotik dalam diet-2. Keputusan menunjukkan diet-1 boleh dijadikan pengganti kepada diet semulajadi bagi penternakan besar-besaran *C. nipponensis* kerana larva yang diternak pada diet-1 menunjukkan jangkamasa larva, kesuburan dan kepanjangan umur dewasa yang lebih baik. Walaubagaimanapun, kemandirian dan berat larva dan pupa lebih tinggi apabila diternak pada *C. cephalonica*. Tiada perbezaan direkodkan antara diet-1 dan *C. cephalonica* dari segi panjang larva peringkat ketiga, kapsul kepala larva peringkat kedua dan ketiga, % pengeluaran dan panjang badan dewasa. Hasil kajian jadual hidup menunjukkan kadar kematian tertinggi *C. nipponensis* apabila di ternak pada telur *C. cephalonica* adalah 37.26% dalam peringkat tidak matang (larva peringkat pertama, ke-2 dan ke-3 dan pupa) .Nisbah seks (kadar betina kepada jantan) dalam diet semulajadi dan tiruan adalah masing-masing pada 0.93:1.00 dan 0.87:1.00. Betina yang diternak pada diet tiruan hidup satu hari lebih lama berbanding pada telur *C. cephalonica*. Maksimum jangkamasa hidup betina diperhatikan apabila diternak pada diet tiruan. Kadar pengeluaran telur yang maksima oleh betina yang diternak pada telur *C. cephalonica* direkodkan pada hari ke-5 adalah 10.4, manakala yang diternak pada diet tiruan mengeluarkan telur yang maksima sebanyak 9.26 pada hari ke-9. Kadar bersih pembiakan (Ro) dan kadar kasar pembiakan GRR) *C. nipponensi* yang didapati pada telur *C. cephalonica* adalah masing-masing pada 69.5 dan 223.1 betina per betina per generasi, manakala pada diet tiruan adalah masing-masing pada 117.24 dan 236.89 betina per betina per

generasi. Min masa generasi (T) dan masa penggandaan populasi *C. nipponensis* juga lebih tinggi pada diet tiruan. Walaubagaimanapun, kadar pertambahan intrisik (r) dan terhingga (λ) (betina per betina per hari) *C. nipponensis* lebih tinggi apabila diternak pada telur *C. cephalonica*. Kajian tindak balas berfungsi ke atas larva peringkat ke-3 *C. nipponensis* yang diternak pada diet tiruan dan telur *C. cephalonica* menunjukkan tindak balas berfungsi jenis-2 terhadap densiti pelbagai afid (*Aphis craccivora*), koya (*Paracoccus marginatus*) dan lalat putih (*Bemisia tabacci*). Berdasarkan persamaan Holling's disk, kadar pencarian yang tertinggi (á) larva adalah masing-masing 0.68 dan 0.40 terhadap koya dan lalat putih yang diternak pada diet tiruan dan telur *C. cephalonica*. Larva yang diternak pada kedua-dua diet menunjukkan masa pengendalian yang maksimum ke atas lalat putih. Larva *C. nipponensis* yang diternak pada kedua-dua diet juga mempamerkan kadar pemangsaan yang maksimum ke atas koya manakala kadar pemangsaan yang minimum pada lalat putih. Kadar R^2 adalah sama direkodkan oleh larva terhadap afid, koya dan lalat putih yang diternak pada diet tiruan dan telur *C. cephalonica*. Green lacewing yang baru direkodkan sangat penting sebagai pemangsa dalam agro-ekosistem di Malaysia. *C. nipponensis* yang diternak pada diet tiruan berasaskan halia menunjukkan keserasian atau prestasi yang lebih baik bagi pelbagai parameter biologi dan pemangsaan, oleh itu boleh digunakan untuk ternakan besar-besaran pemangsa serangga perosak berbadan lembut.

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I certify that a Thesis Examination Committee has met on 06 May 2016 to conduct the final examination of Shafique Ahmed on his thesis entitled "Artificial Diets and Their Effects on Biological Performance of Green Lacewing, *Chrysoperla nipponensis* (Okamoto) (Neuroptera: Chrysopidae)" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory committee were as follows:

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CHAPTER 1

INTRODUCTION

Human interests are always threatened by the presence of pests and pesticides as the most extensively applied methods for pest control. Approximately 2.7 million tons of pesticides were applied in the world in 2011 to control noxious pests (FAOSTAT, 2013). However, pesticide usage has many adverse effects on human and their environment, often resulted in pest resurgence and the killing of non target and beneficial individuals (Weathersbee and Mckenzie, 2005). Moreover, either directly or indirectly, pesticides are responsible for over 25 million cases of pesticide poisoning and 20,000 unintended deaths (Hajek, 2004; Ulhaq *et al*., 2006). Considering these adverse impacts, scientists always strive for alternate methods to control pests that could provide better pest management with less hazards to humans and their environment. During recent years, the use of biological control agents has shown potential to manage pest populations below their economic threshold. Accordingly, many integrated management programs with biological control as their key component have been employed against many damaging pests in various crops throughout the world (Canard *et al*., 1984).

Biological control is a method to control pests through the use of natural enemies as it is environmentally sound and economically efficient in mitigating the pest densities (Sarwar *et al.*, 2012, 2013a, 2013b and 2014). The natural enemies are used in classical, augmentative and inundative biological control programs (Tauber *et al*., 2000). Predators, parasitoids and pathogens are the main groups of natural enemies widely used in the world. Among these, the role of predators to control many agricultural insect pests has been exploited in many countries of the world (Bram and Bickely, 1963, DeBach and Hagen, 1964, Henry, 1979, 1985 and 1993 and Brooks, 1994).

Green lacewings (Neuroptera: Chrysopidae) are important group of insect predators that have a wide geographic distribution and occur in many different cropping systems (Bai *et al*., 2005; Jiang and Xiao, 2010). Lacewing larvae are widely and effectively used as effective biological control agents against several insect pests (Harbaugh and Mattson, 1973; Sattar *et al*., 2007) due to their voracious feeding habits against soft-bodied insects such as aphids, mealybugs, white flies, leafhoppers, psyllids, thrips, caterpillars, insect eggs, mites and spiders (Rashid *et al.*, 2012). Lacewing larvae have relatively short life cycle, a wide host range, have efficient searching ability and resistance against some widely used pesticides (Wihtcomb, 1964; Ridgway *et al*., 1970; Sattar *et al*., 2007; Sattar and Abro, 2011).

In Malaysia, availability of a huge diversity of biological control agents suggests their role in pest management in different agriculture and forest ecosystems (Wong, 1984; Chong, 1986; Ooi, 1986; Sajap *et al*., 1997; Farikhah *et al*., 2007). Various promising species of the family Chrysopidae such as *Chrysopa* sp., *Ankylopteryx*

octopunctata F., *A. trimaculata* Gerst., *Nothochrysa evanescens*, Mch., *Italochrysa aequalis* Walk and *Glenochrysa* sp. have been reported in Malaysia (Yunus and Ho, 1980; Sajap *et al*., 1997; Farikhah *et al*., 2007).

Considering the importance of predators, especially green lacewings in pest management (Hagley, 1989; Maisonneuve and Marrec, 1999; Atlihan *et al*. 2004; Pappas *et al*., 2011), several efforts have been made to preserve and enhance their population density to get the desired results (McEwen *et al*., 1995). However, maintenance of continuous and large predator populations required the continuous supply of their prey species. But, due to unpredictable environmental conditions, continuous supply of natural prey species for rearing predators becomes very difficult. Accordingly, many efforts have been made for the mass rearing of predators on artificial diets to ensure maintenance of enough predator populations for their inundative and augmentative release against many noxious insect pests (Larock and Ellington, 1996). However, mass rearing of predators on artificial diet necessitates that diet is nutritionally adequate to induce feeding in the rearing insects and support their various physiological and biological processes (Cohen, 2004).

Artificial diets are classified in three different categories i.e., holidic diets, in which all ingredients are defined chemically; meridic diets, in which most of the ingredients are known chemically and oligidic diets, in which few of the ingredients are known chemically (Dougherty, 1959). Rearing of *Chrysoperla carnea* has been mostly based on holidic and meridic methods and many studies have been conducted on biological parameters of the *C. carnea* reared on such diets (Tauber *et al*., 1973; Zaki *et al*., 2001). The first artificial diet consisting of protein, lipid, carbohydrate, cholesterol, and water was developed by Cohen and Smith (1998) for mass rearing of *C. carnea.* The development of artificial diets for mass production of predators has greatly increased their capacity, reduced the production cost and enhanced their potential for the successful augmentative biological control programs (Cohen and Smith 1998; Lee and Lee, 2005).

Although, a large development has been done on larval artificial diets, but the chemically defined diets are usually more expensive and require further improvements to make them more economical (Nordlund *et al*., 2001). Moreover, in Malaysia little or no systematic work has been done on artificial diets for the rearing of recently recorded *C. nipponensis* and its role in the management of various agricultural pests. Therefore, studies were carried out to develop and evaluate larval artificial diets with the objective to improve the biological performance of *C. nipponensis* in the regulation of pest populations.

The objectives of the study were:

1. To evaluate the effects of natural and artificial diets on survival, development and reproduction of *C. nipponensis* (Neuroptera: Chrysopidae).

2. To compare growth parameters of *C. nipponensis* (Neuroptera: Chrysopidae) reared on natural and artificial diets.
3. To study the functional responses of *C. nipponensis* (Neuroptera: Chrysopidae) reared on natural and artificial diets.

The information obtained from this study could be utilized for the development of quality mass rearing technique of *C. nipponensis* to ensure maintenance of their enough population for successful IPM against various noxious insect pests.

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