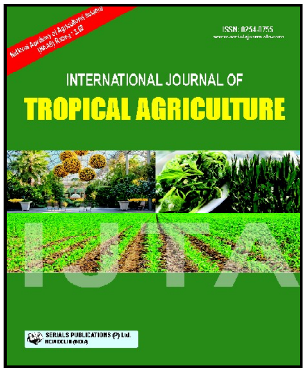

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Conservation of Insect Predators for Pest Management

K. Nishikanta Singh, R. R. Rachana*, Th. Johnson and R. Varatharajan

Centre of Advanced Study in Life Sciences, Manipur University, Imphal – 795003
E-mail: rvrajanramya@gmail.com
** National Bureau of Agricultural Insect Resources, Bengaluru – 560024*
E-mail: vavarachana@gmail.com

Abstract: Different methods of conservation of insect predators such as strip farming, habitat manipulation, production of pesticide and temperature tolerant predators, utility of host plants, molecular characterization of different strains of predatory species and mass production methods of Coccinellid beetles and Neuropteran Chrysopids are briefly reviewed in the context of pest management.

Key words: Chrysopids, coccinellids, thrips, conservation, insect predator, pest management.

INTRODUCTION

Conservation of natural enemies is undoubtedly one of the most important, easily available, simple and cost effective strategy in the pest management. Most of the predatory insects are free living species and their ability to consume a relatively large number of insect preys during the lifespan enables their use as effective bio-control agents. In a functional agro-ecosystem, biological control of insect pest is one of the important methods to control the population of harmful insects, which can be achieved either by introduction or mass multiplication of natural enemies (Weeden *et al.*, 2007). Enhancing the population of natural enemies is possible by means of maintaining refuges for natural bio-agents, conserving weed hosts, use of less persistent insecticides, strip and spot treatment methods etc. In many instances, predators are unnecessarily victimised by the application of chemical pesticides which not only kill the pests but also negatively influence the density of predators. Therefore, the role played by predators can be best understood by the minimal use of chemical pesticides. The impact of pesticide use leads to inability to establish population, reduction in prey consumption, decreased female reproduction, less abundance of prey, poor mobility and ability of predator to recognize the prey, distorted sex ratios etc. (Raymond, 2012). In addition, biotic factors like crop diversity, host plant resistance and tritrophic interactions and abiotic parameters such as climatic change, erratic monsoon, extreme temperature, cyclonic weather also affect the diversity and density of predators. The present paper reviews some of the common methods to augment and conserve potential predators for pest control.

The notable groups of predators comprise the larvae and adult Coccinelids, Carabid, Staphylinid & Cicindelid beetles (Coleoptera), *Chrysoperla* larvae (the green lacewing – Neuroptera), Syrphid larvae and Asilid adults & larvae (Diptera), Wasps (Hymenoptera), Nymphs and adults of the predatory bugs (Heteroptera) (Swamiappan, 1998; Ambrose, 2004). The list of important predators that are being used on selected crops for bio-control programme in India is provided in Table 1. In general, conservation of predators can be achieved both by *in situ* and *ex situ* methods. The *in situ* process includes habitat manipulation like rising plant density and diversity in the selected area, whereas under the *ex situ* technique the predatory insect will be mass multiplied and released in to the field. Each predatory group can be multiplied by its own way. Most of the predators feed on sedentary insects like aphids, mealy bugs, scale insects, and thrips larvae and therefore, unlike parasitoids, augmentation of predatory insects in the laboratory is not a very cumbersome process. Different methods related to conservation of predators are discussed below (Fig. 1).

Effects of host plants on predation

Predators recognise and select the prey through plant host mediated cues (Table 1). Selection of host plant is quite important since its nutritional factors not only influence the growth and development of insect herbivores (prey), but also indirectly alter the fitness of predators through the change of herbivore's quality (Ananthakrishnan, 1992). The tritrophic intricacy between the plant-prey and predator has been well documented in a number of instances

Table 1
Predators for biocontrol programme on selected crops in India

Sl. No.	*Crops*	*Predators*	*Prey Species*
1	Sugarcane	*Pharoscymnus horni* (Weise) *Chilocorus nigritus* (Fab.) (Coccinellidae)	Sugarcane scale insects
2	Cotton	*Chrysoperla* sp (Chrysopidae)	Cotton aphids, American boll worm, thrips and mites.
3	Rice	Lycosid spider, *Cyrtorhinus lividipennis* Reuter (Miridae)	Brown plant hopper
4	Coconut	*Platymeris leavicollis* Distant (Reduviidae)	Rhinoceros beetle
5	Tobacco	*Chrysopa* sp. *Menochilus sexmaculatus* (Fab.) (Coccinellidae)	Cut worm aphid
6	Fruit crops and coffee pests etc.	*Cryptolaemus montrouzieri* (Mulsant) (Coccinellidae)	Grapevine, citrus & coffee mealy bugs

Source: Jayaraj *et al.*, 1994

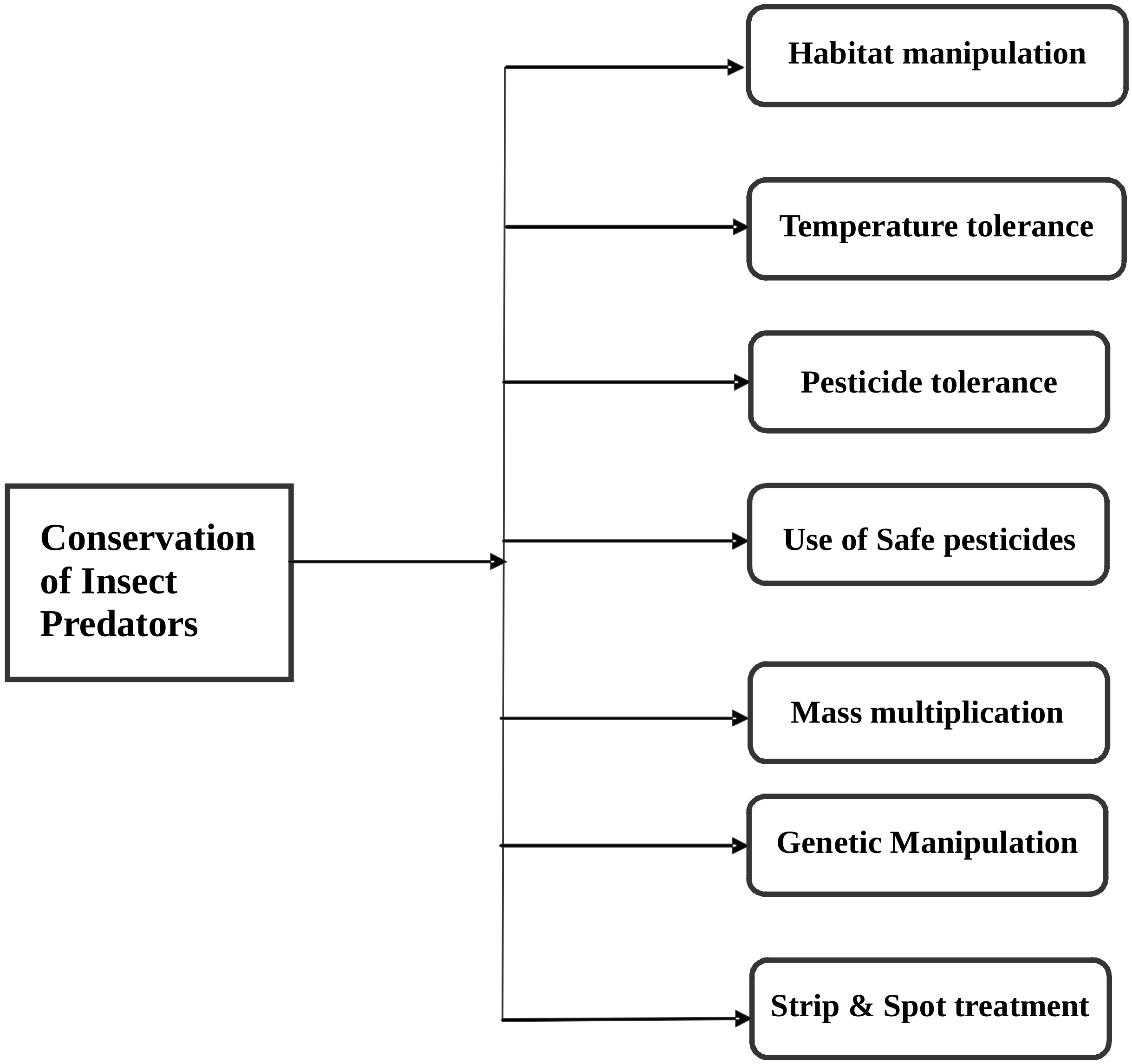

Figure 1: Illustration highlighting methods to conserve insect predators

(Nault & Stryer, 1972; Agarwala *et al.*, 1988). Further, it is also known that the behavioural activity of the predator is also modulated in tune with plant host. As for instance, the anthocorid, *Orius albidipennis* Reuter is an efficient predator of white fly, *Bemisia tabaci* Gennadius and the strawberry spider mite, *Tetranychus turkestani* Ugarov & Nikolski. Banihashemin *et al.* (2017) reported the prey preference of the predator on the plant host - cucumber and sweet pepper. They observed that *O. albidipennis* prefers *T. turkestani* to *B. tabaci* on both the host plants but its preference for *T. turkestani* on sweet pepper is significantly greater than that of cucumber. This might be due to the morphological defensive traits of plants like hairy leaves of cucumber.

In another experiment, Hamdan & Abu-Awad (2007) also studied the effect of plant hosts on the predatory bug, *Orius laevigatus* (Fieber). The tobacco whitefly, *B. tabaci* was offered on tomato and eggplant leaf discs as food source for the predator. They found that adults of *O. laevigatus* fed on both eggs and larval instars of *B. tabaci* maintained on both the hosts with appreciably more preference towards the eggs of *B. tabaci* than the larvae. However, fertility of female *O. laevigatus* was significantly greater when the predator fed on *B. tabaci* reared on tomato than that on eggplant. In yet another observation, collards grown in a weedy background had considerable density of predatory insects belonging to the family Coccinellidae, Chrysopidae and Syrphidae, whereas only a few natural enemies were noticed on collards where weeds were tilled (Shanthi *et al.,* 2006). All these examples highlight the role of plant hosts on the activities of the predator.

Strip farming

Strip-farming is one of the unique cultural practices, which essentially deals with harvesting of alternate strips of host plants so that at any point of time there are two different aged plant growths in the same field. When each set of alternate strip is cut, the other strips are about partially grown such that the field is never completely bare of plants. This method could uphold a better and more reliable population balance between different pest species and their natural enemies can be obtained and retained in a given field. In other words, this process paves way for promoting maintenance of predator density all through the year (Schlinger and Dietrick, 1960).

Habitat manipulation

Habitat manipulation is yet another strategy to conserve the predators, wherein modification of the cropping system is attempted to augment the effectiveness of natural enemies. The advantages of habitat manipulation are manifold and it can be carried out in home gardens or sites having even small scale crop production. Hedge rows, cover crops, mixed plantings and flowering borders enlarge the diversity of habitats which in turn provide shelter and alternative food sources. Pawar (1986) reported that greater the diversity of plant species in the vicinity of the crop, higher the density of predatory insects. Therefore, undoubtedly the plant diversity enhances the abundance of natural enemies which corroborates the concept that biodiversity breeds biodiversity.

Pesticide tolerant predator

Pesticides are double edged weapon. The main objective of applying pesticide is to bring down the density of pest species and in that process, the abundance of natural enemy complex is reduced significantly due to low level insecticide resistance of entomophagous insects as compared to phytophagous prey species. This may be related to the fact that they have lost their ability to adapt to hostile chemicals in the external environment. As early as 1963, Smith *et al.* observed the pesticide tolerance of *Typhlodromus* and *Phytoseiulus persimilis* for nearly half a dozen synthetic organo-chloride compounds *viz.*, aldrin, dieldrin, endrin, kelthane, tetradifon etc. In 1970, the predatory phytoseiid mites resistant to organophosphates were reported from different orchards in USA, Europe and New Zealand. Wilkinson *et al.* (1975) evaluated a number of organophosphate pesticides and found that the mortality rate of *Chrysoperla carnea* (Stephens) and *Hippodamia convergens* Guerin- Meneville was below 27% at minimum level of field dosages of chemicals. The above examples made attempt to search for pesticide resistant predators in India.

As a preliminary exercise, monocrotophos resistant strain of *Chrysoperla* (Chrysopidae: Neuroptera) was developed in Gujarat (Jayaraj *et al.*, 1994) which is an important bio-control agent effectively used to control sucking pests (Athan *et al.,* 2004). Chrysopid predators are known for their resistance to certain chlorinated hydrocarbons and pyrethroids. This is further exemplified with the field collected Chrysopid populations, wherein individuals collected from Sriganganagar manifested higher tolerance to pesticides, followed by Delhi population while Shimla and laboratory cultured populations were quite susceptible to certain insecticides (Venkatesan *et al.*, 2009). Species that are coming under the group *C. carnea* has been acoustically analysed by Charles S. Henry *et al.* (2010) and they found that the Indian populations of *Chrysoperla* mostly belong to the subspecies *Chrysoperla zastrowi sillemi* Esben-Petersen based on its comparison with *Chrysoperla zastrowi arabica* Henry *et al.* Yet another example of such genetic diversity is the populations of *Cryptolaemus montrouzieri* Mulsant manifesting varying levels of pesticide tolerance between different populations. The experimental populations exhibited tolerant feature to imidacloprid. The New Delhi population was relatively tolerant to deltamethrin followed by Coimbatore population (Rabindra *et al.*, 2010). Presence of such pesticide tolerant predators protects the crop from invading pests as their survival fitness in the environment is greater than that of susceptible predators.

Use of safe pesticides

Insect predators can also be conserved by spraying non-toxic or the least toxic insecticidal formulations at proper dose and duration so that the impact of such products will not affect much on the population build-up of predators. Among different botanicals, the dust formulations of *Bougainvilia spectabilis* and *Pongamia pinnata* recorded maximum level of egg hatching which indicated that they would be safer to the eggs of *C. carnea.* On the other hand, neem oil has been proved to be toxic to insect predator since it reduced the larval emergence and its effects were on par with dimethoate and malathion. Generally, the dust formulations of *B. spectabilis* and *P. pinnata* proved to be relatively safe to all stages of *C. carnea* (Ravikumar *et al.*, 1999). Further, periodical monitoring of predator density will also help in taking decision to spray the chemical at appropriate time.

Temperature tolerant predator

India is endowed with over a dozen agro climatic zones having varied climatic pattern ranging from an average minimum temperature of 8^0C to an average maximum of 42^0C (Venkataraman & Chattopadhyay, 2011). Therefore, predatory species which are capable of withstanding a wide range of temperature will be ideal for bio-control programmes. Although each species will have an optimum range of temperature, most insect activity and reproduction occur between 15 and 35^o C. Insects are incredible in producing heat shock proteins to resist higher temperature which in turn facilitates the insects to tolerate a little higher degree of temperature. The desert ants, *Cataglyphis bicolour* (Formicidae) can withstand a critical thermal maximum of 55 ± 1^0C and are known to forage in surface temperature of about 60^0C (Sherwood, 1996). Attempts to search for such capability resulted in the discovery of populations of *Chrysoperla* in our country to be tolerable to the higher range of temperature (32–38^0C). But, with the increase of temperature above the normal range, adult emergence was found to be delayed. However, field collected populations of *Chrysoperla* survived better at variable range of temperature compared to the indoor reared population (Rabindra *et al.*, 2010).

Molecular characterization of insect predators

Intra specific variation is a feature common among the insects which may be under the influence of their geographical location or climatic variation or due to food plant or prey species. A few predatory species are host-specific but many are stenophagic or euryphagic in terms of prey selection. As they tend to exhibit morphological variation, it becomes critical to determine the identity of the predator. Proper identification with the help of morphological as well as molecular methods becomes essential for rearing *en masse* and field release. Hence, molecular characterisation is vital, especially when the predatory organisms appear as sibling species or cryptic in nature. Also proper recognition of species and strain will have better impact on the mass multiplication of predator as a biological control agent. This will enable us to narrow the host range of predators and to direct them against a particular insect pest. Under such condition, molecular techniques will play a pivotal role in solving the problem of inadequate systematics for certain predatory forms. Subjecting the samples in to such process will lead to the identification of genes which can be assessed to evaluate the genetic relatedness between the closely related species. In this context, it is worth mentioning that genes with greater degree of evolution have been found useful to compare closely related predatory species. In spite of the fact that such molecular tools enable us to resolve species ambiguity; this field of research needs more concentrated in-depth analysis for its application. One such effort in this direction is the process of species identity of the prey that being consumed by the predator. The gut content of the predator was subjected to cytochrome oxidase – I evaluation. Species specific COI primers were designed to determine the role of *Karnyothrips flavipes* (Jones), a predator of *Hypothenemus hampei* (Ferrari). The experiment was based on detection of small amounts of prey (*H. hampei*) DNA in the digestive tracts of the predator (*K. flavipes*) {Jaramillo *et al.*, 2010}. Thus the experiment has explicitly proved the consumption of preferred prey which being evident in the analysis of the gut contents of predator.

Of late, the techniques based on molecular marker have been employed to identify the insect species precisely. The genetic markers are nothing but DNA segment present adjacent to the nucleotide sequence of the desired gene. Therefore, it is possible that such sequences tend to be inherited together generation after generation. At present, isozyme markers and DNA based markers are popular techniques, in which, the samples are subjected to agarose gel electrophoresis in the former method so as to detect variations between banding patterns of different samples. Such dissimilar patterns are interpreted as variations on genetic basis. The main disadvantage of this method is the limited availability of enzyme loci and the pattern of expression that being affected by environmental factors. On the other hand, DNA based markers are more versatile and can differentiate those species possessing even minor morphological differences. Such DNA based markers include AFLP, RAPD, RFLP and SSR etc. As for example, one of the classical exercises on insect predator is the contribution by Venkatesan *et al.*, (2008) on the molecular characterisation of *C. carnea* using ITS-2-RFLP method & RAPD assay to distinguish two populations of *C. carnea* from Punjab and Delhi.

Wolbachia induced genetic diversity

The bacteria which belong to the genus *Wolbachia* appear to induce "thelytoky" among the arthropods leading to production of only females by parthenogenesis (Stouthamer & Werren, 1993). This phenomenon exists among certain predatory insects and so, it is sensible to exploit them for biocontrol. Females are more effective agents than males and thelytoky helps in reducing the production cost and field utility. Besides, the rate of population increase in thelytokous form is also very high. In this context, mention may be made on the discovery of *Wolbachia* from the body of *Franklinothrips vespiformis* (Crawford). Females of this species are not only bigger in size, but also more efficient in predation than the males (Arakaki *et al.*, 2001). Such unique property of certain predators enables to check the field density of soft bodied small sucking pests under the natural conditions.

Mass production of predators

Many researchers have made attempt to produce predators *en masse* in the laboratory by simple processes. Some of the practical methods are explained below. The lady bird beetles *viz*., *C. montrouzieri, Scymnus coccivora* (Ayyar), *Nephus* spp., *Chilocorus nigrita* (Fabricius) and *Pharoscymnus horni* (Weise) are commercially produced for field release against mealy bugs and scale insects (Manjunath, 1998). The citrus mealy bug, *Planococcus citri* (Risso) and scale insect *Aspidiotus destructor* Sign are mass reared on fully ripened red pumpkins and their life cycle takes 4-5 weeks and 6-7 weeks, respectively. The crawlers of these insects are used for re-infestation on pumpkin, besides feeding the predators. The report from Bio-control Research laboratories (BCRL), Bangalore states that BCRL has been supplying about 5 lakhs of lady beetles every year to different parts of the country and they advise release of 600 to 1000 beetles per acre (Manjunath, 1998). Mayadunnage *et. al.* (2009) reared syrphid larvae and pupae separately in glass bottles in the laboratory by feeding them with cabbage aphid. They recorded the highest number of syrphid larvae during the peak occurrence of aphids. Simeonidis (1995) developed technique for mass rearing of *Micromus tasmaniae* Walker (brown lacewing) and it was reared in batches of 50, 100 and 200 in 20 litre clear plastic containers. The oats aphid, *Rhopalosiphum padi* L. was fed to the larvae. He observed that the highest initial egg density (200 eggs per container) produced the cheapest adults at 22 cents per adult.

Chrysopid larvae of the order Neuroptera are another group of predators feeding on soft bodied sucking pests such as aphids, thrips and whiteflies. Over 65 species of Chrysopids are reported from our country and among them, *C. carnea* (group) has been extensively studied for mass rearing and field release purposes. Yadav *et al.* (1998) have made pioneering research in the process of culturing and mass rearing of chrysopids under the auspicious of "All India Co-ordinated Research Project on Biological Control". Similarly, Murai and Ishii (1982) described mass production of common flower thrips in which, *Thrips tabaci* Lindeman and *Thrips hawaiiensis* (Morgan) can be reared in a glass tube of 8 x 5 cm size with both the ends being covered with stretched cellophane membrane and within which pollens and honey solution can be supplied as food. The adult female oviposits in between the membrane and the emerging larvae can be used for rearing predatory thrips. Boyd and Held (2006) observed the potentials of *Androthrips ramachandrai* Karny as a biocontrol agent by rearing them with the larval colony of Gall inducer *Gynaikothrips*. Mahyoub *et al*. (2013) developed a method for the mass production of seven spotted lady beetle, *Coccinella septempunctata* (L.). They planted the broad bean, *Vicia faba* L. on plastic trays (25 x 40 x 15 cm^3) or porous foam trays (60 x 25x 20 cm^3 with 109 holes) which contained the peat moss. The bean leaves were infested with *Aphis fabae* Scopoli which distributed over the new foliage of cultivated trays. The infested trays were observed until the population of *A. fabae* increased and became suitable prey to the ladybird beetle, *C. septempunctata*. When the population of *A. fabae* increased to a level of suitable density (approximately 100 individuals per plant), individuals of *C. septempunctata*, the stock of ladybird was procured from the infested plants and then transferred to rearing cages (30 cm diameter x 25 cm height) in the laboratory @ 10 adult males and females each, so that they breed and perpetuate giving rise to next generation.

CONCLUSION

Conservation of predatory insects is certainly one of the most important cost effective methods of pest control. To conserve such beneficial insects, a number of ways are available. It is essential to take up all the possible conservation methods in a holistic manner in order to promote effective conservation. Hence, adoption of all possible methods in a composite way would enhance the chance of conservation of insect predators. Under certain circumstances, even if one or two methods fail to work under the field condition, the remaining strategies will compensate and take care. Field release of predators after mass rearing them in the laboratory (inundative method) seems to be better than that of inoculative technique and it should be continued as part of the predator conservation mechanism till the given ecosystem is enriched with appreciably good density of predators. Such process will pave way for not only field regulation of pests, but also enhance the perpetuation potentials of predatory insects in the natural ecosystem.

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REFERENCES

Agarwala, B.K., Das, S. & Senchoudhuri, M. (1988). Biology and food relations of *Micraspis discolour*(F.): An aphidophagous coccinellid in India. *J. Aphidology*, **2:**7-17

Ambrose, D.P. (2004). Insects and the biotic environment. In: *The Insects: structure, function and biodiversity*. Kalyani Publishers, Pp. 571.

Ananthakrishnan, T.N. (1992). *Influence of chemical profiles of host plants on the infestation diversity of Retithripssyriacus.* Journal of Biosciences, **17**(4): 483-489.

Arakaki, N., Miyoshi, T., & Noda, H. (2001). *Wolbachia*-mediated parthenogenesis in the predatory thrips *Franklinothrips vespiformis* (Thysanopera: Insecta). *Proc. Biol.Sc.*, **268**(1471): 1011-1016.

Athan, R., Kaydan, B. & Ozgokce, M.S. (2004). Feeding activity and life history characteristics of the generalist predator, *Chrysoperla carnea* (Neuroptera: Chyropidae) at different prey densities. *J. Pestic. Sci.* **77**: 17-21.

Banihashemin, A. S., Seraj, A. A., Yarahmadi, F. and Rajabpour, A. (2017). Effect of host plants on predation, prey preference and switching behaviour of *Orius albidipennis* on *Bemisia tabaci* and *Tetranychus turkestani*. *International Journal of Tropical Insect Science,* **37**(3)**:** 176-182.

Boyd D.W. Jr. and Held D.W. (2006). *Androthrips ramachandria* (Thysanoptera: Phlaeothripidae): An introduced thrips in the United States. *Florida Entomologist*. **89** (4): 455-458

Charles S. Henry, Stephen J. Brooks, James B. Johnson, T. Venkatesan and Peter Duelli. (2010). The most important lacewing species in Indian agricultural crops, Chrysoperla sillemi (Esben-Petersen), is a subspecies of Chrysoperla zastrowi (Esben-Petersen) (Neuroptera: Chrysopidae), *Journal of Natural History*, **44**:41-42, 2543-2555, DOI:10.1080/00222933.2010.499577.

Hamdan, A. & Abu-Awad, I. (2007). Effect of Host Plants on Predator Prey Relationship between Predatory Bug, *Orius laevigatus (Fieber) [Hemiptera: Anthocoridae]* and Tobacco Whitefly, *Bemisia tabaci (Gennadius) [Homoptera: Aleyrodidae]*.An - *Najah Univ. J. Res.* (N. Sc.). **21.**

Jayaraj, S., Ananthakrishnan, T.N. & Veeresh, G.K. (1994). *Biological Pest Control in India: progress & perspectives*. Rajiv Gandhi Institute for Contemporary Studies, 25-38.

Jaramillo, J., Chapman, E.G., Vega, F.E. & Hardwood, J.D. (2010). Molecular diagnosis of a previously unreported predator-prey association in coffee: *Karnyothrips flavipes Jones (Thysanoptera: Phlaeothripidae)* predation on the coffee berry borer. Springer, **1**: 185-200.

Mahyoub, J.A., Mangoud, A. A. H., AL-Ghamdi, K.M. & Al- Ghramh H. A. (2013). Method for mass production the seven spotted lady beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae) and suitable manipulation of egg picking technique. *Egypt. Acad. J. Biolog. Sci*., **6**(3): 31 -38.

Manjunath, T. M. (1998). Mass production and application of Biocontrol agents. In: T.N. Ananthakrishanan (Ed.) *Technology in Biological Control.* Oxford & IBH Publishing CO. PVT. Ltd., New Delhi.

Mayadunnage, S., Wijaya gunasekara, H.N.P, Hemachandra, K.S. & Nugaliyadde, L. (2009). Occurrence of *Aphidophagous Syrphids* in Aphid Colonies on Cabbage *(Brassica oleracea)* and their Parasitoids. *Tropical Agricultural Research*, **21**(1): 99 – 109.

Murai, T. & Ishii, T. (1982). Simple rearing method for flower thrips (Thysanoptera: Thripidae) on pollen. *Japanese Journal of Applied Entomology &Zoology*,**26**:149-154

Nault, L.R. & Styer, W.E. (1972). Effects of sinigrin on host plant selection by aphids. *Ent. Exp. Appl.*, **15**: 423-437.

Rabindra, R.J., Ballal, C.R., Jalali, S.K. & Venkatesan, T. (2010). Biodiversity of insect biocontrol agents In, *Insect Biodiversity: Functional dynamics and Ecological Perspectives*. (Ed.) Ananthakrishnan, T.N. Chapter V**,** 69-88.

Ravikumar, S.S., Gond, K. B., Kulkarni, K.A. & Lingappa, S. (1999). Evaluation of plant products against natural enemies of safflower aphid *Chrysoperla carnea* Stephens and *Coccinella septempunctata* L. in the laboratory. In S. Ignacimuthu & S.J. Aloke Sen (Eds.) *Biopesticides in Insect Pest Management*.

Pawar, A.D. (1986). Role of natural enemies in the integrated pest management of rice. *Plant Protection Bulletin*, India, **38**: 15-26.

Raymond, C. (2012). *Indirect effects of pesticides on natural enemies* In, Dr. R.P. Soundarajan (Ed.) Advances in chemical and botanical pesticides. 14 Sept. 2017. *www.intechopen.com/books/pesticides-advances-in-chemicals-and-botanicals.*

Schlinger, E. I. & Dietrick, E. I. (1960). *Biological control of insect pests aided by Strip-farming Alfalfa in experimental program*. Carlifornia Agriculture. Pp. 1-8.

Shanthi, R., Hussain, K. J., Sanjayan, K. P. & Muralirangan, M. C. (2006). Dispersal of insect pest and predator complex in a heterogenous agro-ecosystem of Tamil Nadu. In: S. Ignacimuthu & S. Jayaraj (Eds.) *Biodiversity and Insect Pest Management*. Narosa Publishing Home, New Delhi.

Sherwood, V. (1996). *Most Heat Tolerant*. University of Florida Book of Insect Records, Pp. 49-51.

Simeonidis, A. (1995). Development of a mass rearing technique for the Tasmanian brown lacewing, *Micromus tasmaniae* Walker, Pp. 17.

Smith, F.F., Henneberry, T. J., & Boswell, A.L. (1963). The pesticide tolerance of *Typhlodromus fallacis* (Garman) & *Phytoseiulus persimilis* A.H. with some observations on predator efficiency of *P. persimilis*. *Journal of Economic entomology*, **56**(3): 274-278.

Stouthamer, R. & Werren, J.H. (1993). *Microbes associated with parthenogenesis in wasps of the genus Trichogramma*. J. Invertebr. Pathol.,**61**:6-9.

Swamiappan, M. (1998). Commercial production of biopesticides- feasibility, ethics and certain considerations. In: T.N. Ananthakrishanan (Ed.) *Technology in Biological Control*. Oxford & IBH Publishing CO. PVT. Ltd., New Delhi.

Venkataraman, K. & Chattopadhyay, A. (2011). *Biodiversity and its conservation*. National Symposium on biodiversity status and conservation strategies with special reference to north-east India, Manipur University, Pp. 13-31.

Venkatesan, T, Poorani, J., Jalali, S.K., Srinivasamurthy, K., Ashok Kumar, G., Lalitha, Y. &Rajeshwari, R. (2008). Confirmation of the occurrence of *Chrysoperla zastrowi arabica* Henry et al. (Neuropteran: Chrysopidae) in India. *Journal of Biological Control,* **22**(1): 143-147.

Venkatesan, T, Jalali, S.K., Srinivasamurthy, K., Rabindra, R. J. & Lalitha, Y. (2009). Occurrence of insecticide resistance in field populations of *Chrysoperla zastrowi arabica* (Neuroptera: Chrysopidae) in India. *Indian Journal of Agricultural Sciences,* **79** (11): 910-912.

Weeden, C.R., Shelton, A.M. & Hoffman, M.P. (2002). *Orius tristicolor and O. indisidiosus*. Biological control: a guide to natural enemies in North America. 14 Sept. 2017. <http: www.nysacs.cornell.edu/ent/biocontrol/predators/orius.html>.

Wilkinson, J.D., Biever, K.D. & Ignoffo, C.M. (1975). *Contact toxicity of some chemical and biological pesticides to several insect parasitoids and predators.* Springer Link, **20**(1): 113-120.

Yadav, D.N., Joshi, B. C., & Parasara, U. A. (1998). Mass rearing technique for two Chrsopid predators, *Chrysoperla carnea* Steph. & *Mallada boninensis* Okamota. In: T.N. Ananthakrishanan (Ed.) *Technology in Biological Control*. Oxford & IBH Publishing CO. PVT. Ltd., New Delhi.