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Review Article

Exploitation of egg parasitoids for control of potential pests in vegetable ecosystems in India

Aswatha Krishnamoorthy

Indian Institute of Horticultural Research, Bangalore, India
Corresponding author, e-mail: akmurthy@iihr.ernet.in

Abstract

In vegetable ecosystem the egg parasitoids are mainly Trichogrammatids (*Trichchogramma, Trichogrammatoidea*) on Lepidoptera, Secelionids (*Telenomus*, *Trissolcus*) on Lepidoptera and Hetroptera, and Mymarids on leafhopper and thrips. *Trichogramma chilonis* is found promising as a natural and augmentation control agent for several lepidopteran pests. Considerable progress has been made on utilizing kairomones for improving the performance of *T. chilonis*. Release systems should be refined to match with host abundance pattern, while a novel method of spraying parasitized eggs has been found promising. Inundative releases of *T. chilonis* , *T. brasiliensis* and *T. pretosium* for *Helicoverpa* control in tomato, Okra and chilli, besides *T. chilonis* for *Leucinodes orbonailis* on brinjal have been demonstrated to be effective. Similar promising results have been obtained from *Trichogrammatoidea bactrae* and *T. brassicae* release in controlling *Plutella xylostella* on cabbage. Integration of egg parasitoid release with NVP, neem and pheromone trap has been shown possible in IPM modules. The scope of mass rearing of *Telenomus remus* on *Corcyra cephalonica* has been demonstrated, while further improvements in their efficiency are required. The present constraint in mass production and storage of *T. achaea* may merit attention. Further research may focus also on strains collection for stress adaptation, host searching and also on field dispersal and utilization of semiochemicals for improving the field performance of mass- released parasitoids.

Key words: vegetable ecosystem, trichogramatids, sceliouids, strains, kairomones, integration

Exploração de parasitóides de ovos para o controle de pragas potenciais em ecossistemas vegetais na Índia

Resumo

No ecossistema vegetal, os ovos de parasitóides são principalmente tricogramatídeos (Trichchogramma, Trichogrammatoidea) em Lepidoptera, Secelionídeos (Telenomus, Trissolcus) sobre Lepidoptera e Hetroptera, além de Mimarídeos sobre cigarrinha e tripes. *Trichogramma chilonis* é tido como um promissor agente natural de controle e reforço de diversas pragas lepidópteras. Um progresso considerável foi feito na utilização cairomônios para melhorar o desempenho de *T. chilonis*. Sistemas de libertação podem ser refinados para corresponder ao padrão de abundância do hospedeiro, enquanto que um novo método de pulverização de ovos de parasitas também tem sido visto como promissor. Liberações inundativas de *T. chilonis*, *T. brasiliensis* e *T. pretosium* para o controle de Helicoverpa em tomate, quiabo e pimenta, além de *T. chilonis* para *Leucinodes orbonailis* em berinjela têm demonstrado ser bastante eficaz. Similares resultados promissores foram obtidos a partir da liberação de *T. bactrae* no controle de *Plutella xylostella* em repolho. A integração da liberação dos ovos de parasitóides com armadilha de NVP, nim e feromônio foi demostrada como possível em módulos IPM. O escopo de criação massal de *Telenomus remus* sobre *Corcyra cephalonica* foi demonstrado, no entanto, algumas melhorias em sua eficiência são obrigatórias. A restrição presente na produção em massa e armazenamento de *T. acaia* merece atenção. Futuras pesquisas podem se concentrar também na coleta de amostras para a adaptação ao estresse, busca de acolhimento e também na dispersão de campo e utilização de semioquímicos na melhora do desempenho em campo da massa de parasitóides liberados.

Palavras-chave: ecossistema vegetal, trichogramatídeos, scelioudeos, variedades, cairomônios, integração

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Introduction

Production of vegetables without the use of insecticides is becoming imperative because of harmful nature of insecticide residues on the produce and pests often developing resistance to several insecticide molecules, one after the other, after hitting the market. Several rounds of insecticides are required to be applied on vegetable crops for successful production because pests show much resistance. This limits the cultivation of vegetables amidst fluctuating market price. Poor market price hits cultivation in rural, semi-urban and urban areas. Increased cost of cultivation is mainly due to ineffectiveness of chemicals or development of resistance by the pests. Availability of spurious chemicals in the market also adds fuel to the fire. Alternatively, biological control method is sought after for the control of some pests, if not all. Classical biological control attempt cannot be used successfully in short duration annual crops like vegetables, ornamentals and field crops, since their ecosystems are in continuous flux and the extent of area under cultivation is also often low. This clearly suggests the need to find out alternative ways to overcome this problem. A great extent of pest problems associated with short duration crops can be circumvented by adopting an active biological control method (inundative release) rather than passive method (classical or inoculative release) of control. This is because, in any short duration crops like vegetables, the pest activity is observed only during a limited period; more consideration is to be given for the pest that attacks either during early or mid phase of crop growth and causes considerable economic yield loss. Therefore, potential biological control agents should be directed during that period in such a way that the pest(s) is/are killed effectively before causing serious economic damage. Unlike insecticides, biological control agents are not broad - spectrum. Each pest needs to be tackled with different species of biocontrol agents. Similarly, each stage of the pest also needs to be tackled with its own or related natural enemy.

Scattered information is available on egg parasitoids of a few pests of vegetable crops. Detailed studies such as biology, mass rearing, field releases, etc. with special reference to a few species of egg parasitoids are available. Therefore in the present paper, an attempt to link information available overseas has been made, in order to provide tangible solution in the control of pests under vegetable cropping systems based on information on egg parasitoids recorded or reported from vegetable cropping systems in India and its effectiveness.

Potential egg parasitoids

Egg parasitoids of the family, Trichogrammatidae, Scelionidae and Mymaridae play a significant role on the control of pests on vegetable crops. Majority of insects belong to Trichogrammatidae attack eggs of Lepidopterans. Notable genera are *Trichogramma* and *Trichogrammatoidea*. Similarly, among Scelionidae, species of *Telenomus* and *Trissolcus* are important egg parasitoids of Lepidopterans and Heteropterans, respectively. Large members of Mymarids attack eggs of leafhopper, thrips, etc.

Reports and records of egg parasitoids

Efforts were made to peruse four decades of literature pertaining to egg parasitoids (excluding egg-larva, egg-larva-pupa parasitoids) of pests that attack major pests of vegetable crops in India. A comprehensive list of egg parasitoids collected from vegetable cropping systems is furnished in Table 1. *Trichogramma chilonis* Ishii (=*australicum* (Gir.)), *Trichogramma achaeae* Nagaraja and Nagarkatti *and Telenomus sp.* were recorded for the first time from eggs of *Helicoverpa armigera* (Hubn.) infesting tomato in and around Anand, Gujarat (Manjunath et al., 1970). *Trichogramma chilonis* was dominant (2 - 80%), while *Telenomus* was very negligible. Eggs of *H. armigera* laid on marigold intercropped in tomato were parasitized by *T. chilonis* to the tune of 5 – 85% (Manjunath et al., 1970). This indicates that not only the pest was attracted to the bright flowers of marigold but also the parasitoids were. Four species of egg parasitoid *viz., T. chilonis*, *T. achaeae*, *T. agriae* Nagaraja and a species of *Telenomus* parasitized the eggs of *Agrius convoluli* (L.), a pest of sweet potato and *Phaseolus*. Total parasitism under natural conditions rose up to 63.9% (Nagarkatti, 1973). About 8% parasitism of *H. armigera* eggs by *T. chilonis* on okra was observed in Karnataka in 1977 (Thontadarya et al., 1978). Though *T. chilonis* preferred *H.armigera* in tomato fields, it did not prefer the same pest under okra ecosystem. This suggests the influence of cropping systems on the effectiveness of egg parasitoid. *Trichogrammatoidea armigera* Nagaraja was reared from *H. armigera* and *Lampides boeticus* (L.) and *Trichogrammatoidea guamensis* sp. n. reared from *L. boeticus* (Nagaraja, 1978). *Trichogramma chilonis* was found to produce 98.2% parasitism in 1973-74 and 84.2% in 1974-75 in Gujarat on eggs of *H. armigera* collected from potato, tomato, etc. (Yadav, 1980). However, more parasitism of *H. armigera* was observed on potato, but it was less in tomato (Yadav & Patel, 1981). *Trichogramma chilonis* was for the first time reported on eggs of *Acherontia styx* (Westw.) infesting brinjal in Rajendranagar, Andhra Pradesh. The level of natural parasitism ranged from 79-93% under field condition (Rao et al., 1980). Similar natural occurrence of *T. chilonis* was observed under Bangalore conditions also. Total parasitism of *A. styx* eggs in brinjal was 54 – 64 %. From this, 80% was by *T. chilonis,* 17% by *T. achaeae* and 3% by *Telenomus* sp. Each egg yielded a minimum of one parasitoid adult (*Telenomus* sp.)

to a maximum of 27 (*T. chilonis*) (Krishnamoorthy et al., 1999b). *Trichogrammatoidea bactrae* (local strain: originally obtained from the eggs of *Bactra venosana* Zeller attacking nut grass, *Cyprus rotundus* L.) was found to be a potential egg parasitoid of DBM (Krishnamoorthy & Mani, 1999a). *Trichogramma chilonis* exerted significant pressure on *H. armigera* in association with *Campoletis chlorideae* Uchida on potato (Yadav et al., 1984). All these records confirm that *T. chilonis* is the dominant one among the egg parasitoids recorded from *H. armigera* infesting tomato, potato, marigold, etc. Similar observation was also made from *H. armigera* on tomato in Bangalore (Divakar & Pawar, 1982). Sharma & Yadav (1996) reported *T. chilonis* and *T. achaeae* form eggs of *Achaea janata* (L.) collected from tomato fields of Gujarat. Srivastava & Kushawaha (1995) reported 31.8% parasitism of eggs *Spodoptera litura* L. by *T. chilonis* in cauliflower fields of Udaipur, Rajasthan. *Trichogramma chilonis* also attacks eggs of *Plutella xylostella* L. in cabbage fields to the tune of 77.06 to 94.87% on Indian mustard when mustard was used as trap crop in cabbage, 42% on cabbage and 4% on cauliflower. This was reported for the first time from *Gujarat* (Yadav et al., 2001). The eggs of *Agrotis ipsilon* Hufnagel in potato field were parasitized by *T. chilonis* (Badal et al., 2006) (Table 1). Similarly, *T. chilonis* is the predominant egg parasitoid of other lepidopteran such as *A. janata, A. styx, A. ipsilon, P. xylostella, S. litura,* etc., which naturally controls the pest under certain conditions such as no interference from insecticides.

Table 1. Record of egg parasitoids on pests of vegetables in India since 1970.

Crop	Pest	Parasitoid	Family	Field parasitism	Source
Tomato					
	Helicoverpa armigera (Hubn.)	*Trichogramma chilonis* Ishii	Trichogrammatidae	2 - 85%	Manjunath et al. (1970)
		T. chilonis	Trichogrammatidae	84.2% - 98.2%	Yadav (1980) Yadav & Patel (1981)
		T. chilonis	Trichogrammatidae	-	Divakar & Pawar (1982)
		Trichogramma achaeae Nagaraja & Nagarkatti	Trichogrammatidae	-	Manjunath et al.1970
		Telenomus sp.		Negligible	Manjunath et al.(1970)
	Achaea janata L.	T. chilonis T. achaeae	Trichogrammatidae		Urmila Sharma & Yadav, (1996)
?		*Tr. prabhakeri* sp.	Trichogrammatidae	-	Nagaraja (1978)
Brinjal	*Acherontia styx* (Westw.)	*T. chilonis*	Trichogrammatidae	79-93%	Rao et al. (1980)
		T. chilonis T. achaeae *Telenomus* sp	Trichogrammatidae Scelionidae	Total 54 – 64 % 80% 17% 3%	Krishnamoorthy et al. (1999)
	Amrasca biguttula biguttula	*Arescon euocki* *Stethynium empoascae* *Anagrus flavelous*	Mymaridae Mymaridae Mymaridae		Singh et al. (1993)
Potato	*H. armigera*	*T. chilonis*	Trichogrammatidae	84.2% - 98.2%	Yadav (1980) Yadav & Patel (1981) Yadav et al. (1984)
?	*Agrotis ipsilon* Hufnagel	*T. chilonis*	Trichogrammatidae		Badal Bhattacharyya et al. (2006)
Cabbage / Cauliflower	*Spodoptera litura*	*T. chilonis*	Trichogrammatidae	31.8%	Srivastava & Kushawaha, (1995)
	Plutella xylostella L.	*T. chilonis*	Trichogrammatidae	77.06 to 94.87%	Yadav et al. (2001)
Okra	*H. armigera*	*T. chilonis*	Trichogrammatidae	8%	Thontadarya et al. (1978)
	Amrasca biguttula biguttula	*Arescon euocki* *Stethynium empoascae*	Mymaridae Mymaridae		Kapadia & Mittal (1995)
		Arescon euocki *Anagrus sp* *A. flavelous* *Oligosita sp*	Mymaridae Mymaridae Mymaridae Mymaridae		Singh et al. (1993)
? Pea	*Lampides boeticus*	*Trichogrammatoidea armigera* sp.n *T. guamensis* sp.n	Trichogrammatidae Trichogrammatidae	-	Nagaraja (1978)
? Pea	*H. armigera*	*Trichogrammatoidea armigera* sp.n	Trichogrammatidae	-	Nagaraja (1978)
Sweet potato	*Agrius convoluli* (L.)	*T. chilonis,* *T. achaeae,* *T. agriae* *Telenomus* sp	Trichogrammatidae Scelionidae	Total up to 63%	Sudha Nagarkatti (1973)

?: Information on crop is either not available or doubtful.

Among egg parasitoids of the family Scelionidae, a species of *Telenomus* was alone found parasitizing eggs of *H. armigera, Agrius convolvuli* (L.) and *A. styx* (Table 1). Two mymarids, *Arescon enocki* (Subba Rao & Kaur) and *Stethynium empoascae* (*S. triclavatum*) are recorded as parasitoids of *Amrasca biguttula biguttula* (Ishida) infesting okra. Among these, *Arescon enocki* was the dominant parasitoid (Kapadia & Mittal, 1995). *Anagrus* sp and *A. flavelous* Waterhouse*, Arescon enocki* and *Oligosita* sp. parasitized *A. biguttula biguttula* (Singh et al.,1993). *Anagrus flaveolus, Anagrus sp., Stethynium empoascae* and *Oligosita sp.* were active on okra and *A. flaveolus, Arescon euocki* and *S. empoascae* were active on brinjal against *A. biguttula biguttula* (Table 1). Thus, *A. flaveolus and S. empoascae* were common in okra and brinjal fields.

Control of crop damage can easily be achieved by nipping the pest at egg stage itself. Egg parasitoid can search in the field for the presence of eggs of the target pest and kill them by parasitization. Therefore, one has to release the egg parasitoid in large numbers, especially short duration crops like vegetables, to achieve killing of most of the eggs which were laid in the field.

Large scale production of egg parasitoids

For biological control of the pests at egg stage, especially for short duration crop like vegetables, egg parasitoids are best suited biocontrol agents and are required to be mass-produced for augmented large - scale releases in the field. In mass production, proper species (correct identity), potential strain, cost effectiveness, etc. becomes vital. It is very difficult to mass - produce egg parasitoids on natural host insects, as mass production of the host insect will itself be very expensive. Mass production of trichogrammatids was therefore first attempted in India using the fictitious host, *Corcyra cephalonica* (Staint) (Kannan, 1931). Later on, several researchers have tried to use original host and other hosts, such as *Sitotroga cereallela* Oliv. for mass production of trichogrammatids, but *C. cephalonica* was observed to be the most ideal host for mass production (Paul et al., 1981; Rathi et al., 2000). Therefore, among the laboratory hosts tried, eggs of *C. cephalonica* were found more preferred by trichogrammatids, which may be ascribed to the greater size and nutritional value of the host (Paul et al., 1981). The development of *T. chilonis* on the eggs of *C. cephalonica* obtained from moths reared on different cereals, *viz.*, maize, rice, sorghum and wheat revealed that the parasitoid developed faster on sorghum and maize reared host eggs and were equally suitable for parasitism. Parasitoid emergence was higher on host eggs reared on sorghum (91.09%) than on maize (82.91%). The progeny emerging from host eggs reared on maize and sorghum consisted on more females compared to rice and wheat, an important characteristic of a parasitoid species for any biological program (Kumar & Shenhmar, 2003).

An illumination chamber and a parasitization chamber was designed and modified for mass multiplication of egg parasitoid, *T. brasiliensis* on *C. cephalonica* egg cards. Upon placing two parasitization chambers inside the illumination chamber, 21 ml of eggs could be exposed for parasitization at a time, resulting in uniform parasitization of eggs. No specific pattern in parasitization was perceived between the layers of the chamber at different ratios and exposures. Exposure of mother to daughter cards in the ratio of 1:7 for 48 h in the parasitization chamber resulted in optimum parasitization of eggs by the parasitoid *T. brasiliensis*, higher percentage of adult emergence, and less number of runts in the resultant progeny (SreeKumar & Paul, 2003). It was also found that for mass-rearing of *Trichogrammatoidea* near *T. guamensis* Nagaraja the optimum relative density was 1:10 (parasitoid: host eggs) and that the risk of superparasitism was avoided (Varma et al., 1980).

Studies on the feasibility of mass-production of *Telenomus remus* Nixon in the laboratory indicated that noctuids such as *S. litura* and *S. mauritia* Boisd. were preferred. Eggs may be stored at 10 ° C for 10 days and adults can be held at 5-10 ° C for 3 days (Gautam, 1987). However, study on the effect of age of *S. litura* on parasitism by *T. remus* in the laboratory indicated that eggs of 0-72h old were readily accepted by the parasitoid with little detrimental effect on its progeny. Host eggs of more than 72 h old were avoided by the parasitoid (Dass & Parshad, 1983). *Telenomus remus*, though preferring only true host for parasitization, has accepted eggs of *C. cephalonica* as an alternative laboratory host, but initial parasitism was poor. However, after a few generations of continuous rearing on *C. cephalonica*, 100% parasitism was obtained without any significant difference in development period and sex ratio of the parasitoid (Kumar et al., 1986). The eggs of *S. litura* were the most preferred (90.0%), followed by the eggs of *S. exigua* (76.66%), *C. cephalonica*(44.0%) and *H. armigera*(24.66%).The parasitism potential decreased with age, although the 7-day-old parasitoids still exhibited effective parasitism (Murthy et al., 2004).

Biology of egg parasitoids

Life history of several species of egg parasitoids was studied in detail by many researchers and is well documented in literature. However, there were very few who studied the life history of egg parasitoids on pests of vegetables. A laboratory study of *Tricgogrammatoidea bactrae*, a parasitoid of DBM, on *C. cephalonica* at 26±1 °C and 50-80% RH revealed that from each parasitized egg of *C. cephalonica*, up to

2 parasitoids emerged and there were almost equal chances of getting 1 or 2 parasitoids. Each female parasitized a mean of 4.6 and 6.4 eggs of *P. xylostella* and *C. cephalonica* during its mean survival of 1.7 and 2.3 days, respectively, and mean fecundity was 6.3 and 9.1 with a female-biased sex ratio (64.6 and 68.6 % females). The parasitoid failed to emerge from 45.9 and 38.9% parasitized eggs of *P. xylostella* and *C. cephalonica*. During post-embryonic development, 38.1 and 31.9% mortality was observed. Maximum mortality was observed in the pupal stage (Bhardwaj & Gupta, 2002). When the biology of *T. chilonis* was compared by considering eggs of *C. cephalonica* and the eggs of its natural host *H. armigera* under laboratory conditions the developmental period of the female progeny was significantly shorter and fecundity of the female parasitoid was significantly greater for the eggs of *C. cephalonica* than for the eggs of *H. armigera*, but the number of females emerging per day did not significantly differ between both hosts (Shirazi, 2007).

The biology of *Telenomus remus* at different combinations of temperature (23, 27, 30 and 34 °C) and relative humidity (25, 50, 75 and 90%) was studied in the laboratory using *S. litura* as a host. Percentage parasitism was highest at 27 °C and 75% RH. The mean development period ranged from 7 days at 34 °C to 13.7 days at 23 °C. The different levels of relative humidity had no significant effect on the developmental period of *T. remus* (Gautam, 1986).

Effect of storage on the egg parasitoids

Parasitized eggs are stored at low temperatures in order to extend the shelf-life of the parasitoid. This is particularly very essential in the context that mass produced parasitoids at various dates can be stored at low temperature and pooled quantity can be shipped to desired places for large scale field releases. As the storage period increased, parasitoid emergence gradually declined. This storage helps in extending the life of the parasitoid for few more days, which, in turn, helps commercial organization to avoid loss of parasitoids to some extent. Parasitism and emergence was higher (96.0% and 95.3%, respectively) in *C. cephalonica* eggs refrigerated for two days, and lower (3.3%) in eggs refrigerated for 80 days. Increasing the egg storage duration decreased the parasitism by *T. achaeae*. Per cent parasitism was highest up to 20 storage days (Shivaleela & Patil, 2003.). Thus, storage of 2 days was found optimum for mass production of parasitoid.

The major disadvantage with *T. bactrae* was that it could not tolerate low temperatures between 7° C and 10° C and therefore it could not be stored (Krishnamoorthy & Mani,1999c). At these temperatures, emergence and survival were greatly affected even when stored for 3 and 5 days at 7° C and 10° C, respectively (Krishnamoorthy & Mani, 1999d). But in another study, it was found that the parasitized eggs could not be stored for more than 7 days at 10 °C. However, at 15 ° C, storage could be extended up to 18 days but with low emergence (17.2%). In another experiment, eggs exposed to 10 and 15 ° C for 5, 10 and 15 days after 3, 5 and 7 days of parasitization showed satisfactory adult emergence as for eggs stored at 15 ° C for 5 days after 5 and 7 days of parasitization (72.3 and 72.1%), respectively. Adult emergence occurred in storage from eggs stored for more than 5 days at 15°C after 7 days of parasitization. In eggs without adult emergence, mortality often occurred in the pupal stage (55.9 and 61.6% after 3 and 5 days of parasitization), followed by larval (21.3 and 6.6%) and adult stages (22.8 and 31.7%, respectively). The optimum storage for *T. bactrae* was at 15 °C for 10 days after 5 days of parasitization (Gupta & Bhardwaj, 2002).

Preliminary field evaluation: under cage conditions

It is better to evaluate first the performance of the egg parasitoid(s) under large cage conditions or small field conditions before their large-scale release in the field. Further, it is preferable to evaluate naturally occurring egg parasitoid of the pests of vegetable crops which have been reported only from very few vegetable crop pests (Table 1). The species which have shown higher level of parasitism could thereafter be taken up further for releases under large scale field conditions. Egg parasitoids such as *Trichogramma brasiliensis* (Origin: South America), *T. chilonis* and *Trichogramma pretiosum* Riley (Origin: South America) were released against *H. armigera* on tomato in small cages (Table 2). The rate of parasitism recorded was 87.5 to 100% in release cage as against 85 – 93.7% fruit damage in control (Gupta et al., 1984). *Trichogramma exiguum* Pinto and Platner (Origin: South America) caused highest parasitism (100%) of eggs of *H. armigera* under laboratory conditions. *Trichogramma brasiliansis* (98%), *T. chilonis* and *Trichogramma perkinsi* (Girault) (90%) and *T. chilonis* (*=minutum*)(70%) were also found useful for the control of *H. armigera* (Kakar et al., 1990). But the performance of the parasitoid in terms of high level of parasitism obtained under caged conditions does not need to be the same under field conditions, since dispersal (both passive and active) of the parasitoid would affect the level of parasitism greatly. In some cases, the level of parasitism can be enhanced or markedly observed because of the influence of host plant and host insect. To illustrate further this aspect, *T. chilonis* parasitize more number of eggs of *S. litura* on cauliflower than on other host plants (Anonymous, 1993). The level of natural parasitism of *S. litura* eggs on plants like cauliflower, beetroot and cabbage was from 66.6 – 100 % (Singh & Jalali, 1994).

Telenomus remus adults, numbering 3000, produced 100 % parasitism of eggs of *S. litura* (15 egg masses) on cabbage under cage (1.8m^3) conditions, suggesting its potential for exploitation under open field conditions (Krishnamoorthy & Mani, 1985a) (Table 2).

Role of semiochemicals

With a view to improve *T. chilonis* efficiency, a study was conducted on the influence of strain variability and kairomonal substances on its parasitization under multiple-choice assay, which has revealed that irrespective of treatment with kairomonal substances, the highest mean parasitization of *C. cephalonica* eggs (21.5%) was by a strain collected from sugarcane borers (Strain 15) while the least mean parasitization was in eggs exposed to Strain 22. Among the five kairomonal substances tested, hexacosane (0.1%) induced the highest egg parasitization. The interaction between *T. chilonis* strains and kairomones indicated that the combination of Strain 15 and hexacosane (0.1%) was most effective and registered highest egg parasitization (36.6%), followed by the combination of Strain 15 and tricosane (0.1%). The scope of selecting and utilizing the behaviorally responsive strains in combination with their effective kairomones for field release is to be considered (Bakthavatsalam & Tandon, 2006).

Eight different semiochemical dust formulations were prepared with leaf extracts of flowering phase of maize cv. Mahekanchan, sunflower hybrid TCSH-1 and the egg wash of *Chilo partellus* at 2 g/10 ml of hexane, mixing them in different proportions. These dust formulations were evaluated in the field by stapling egg cards of *C. cephalonica* treated with different semiochemical formulations on the underside of the leaves of tomato. The semiochemical dust formulations were prepared using equal proportions of flowering phase leaf extract of Mahekanchan, TCSH-1 and egg of *C. partellus* registered the highest parasitism in the field, followed by the dust formulation prepared using the flowering phase leaf extract of TCSH-1 (2 g/10 ml of hexane). It is suggested that these semiochemical formulations could be used for the efficient management of *T. chilonis* in the field to enhance their parasitization (Paramasivan & Paul, 2005). The response of *T. brasiliensis* and *Trichogramma japonicum* Ashmead was lower to tomato extracts compared to pigeon peas and marigold (*Tagetes indica)*. The presence of tricosane in pigeon pea, hexadecane and octacosane in marigold and octacosane in tomato was presumably responsible for the differential response (Madhu et al., 2000). Hexatriacontane, pentacosane, heptadecene, docosane and 2, 6, 10 – dodecatrienal – 3, 7-11-trimethyl were identified from kairomonally active extracts of the scales of *H. armigera* (a natural host) and *C. cephalonica* (a laboratory host) for response of *T. chilonis* (Ananthakrishnan et al., 1991). Some time even pheromone traps held in the field help to attract egg parasitoid. The response of newly emerged, mated females of *T. chilonis* to two noctuid sex pheromones showed that Helilure (a synthetic pheromone of *H. armigera*) was attractive, while spodolure (a synthetic pheromone of *S. litura*) was not (Padmavathi & Paul, 1996).

The efficacy of different *Trichogramma* species (*T. chilonis, T. achaeae, T. pretiosum* and *T. brasiliensis*) against the chilli fruit borer (*H. armigera*) was investigated in the greenhouse. *Trichogramma chilonis* produced the highest level of egg parasitism at 3, 5 and 7 days after release (18.22, 28.07 and 37.93%, respectively), followed by *T. pretiosum, T. brasiliensis* and *T. acheae* (Chandrashekhar et al., 2003)

Release strategy

Based on the study conducted by several researchers on various vegetable crops, it is suggested that a weekly release of 50,000 adults ha^{-1} should be minimum made at weekly interval. Since egg parasitoid survives around 6-7 days, it is advisable to make weekly releases in the field for enabling them to gradually get established. Once established, the field population along with released population will suppress the pest population in the field. A minimum of 5-6 releases are required for appreciable level of pest control.

Particularly for inundative releases of species of trichogrammatids, one should determine the distances from which the parasitoids should be released. It was observed that *T. pretiosum* exerted varying degree of parasitism of *C. cephalonica* eggs when placed at different distances from the central point of release in tomato field. Parasitization levels of eggs kept at 1, 2, 3, 4, 5, 6 and 7 m distance from the release point averaged 75, 63, 50, 26, 22, 13, 6 and 2 %, respectively (Mehetre & Salunkhe, 2000). Thus, to get a better result, the egg cards should be tied on the plant at least 1-3m apart. Although it will vary among different crops, a distance of 3m between the two release points appears ideal, so there will be i.5m radial distance from point of release for the egg parasitoid effectively search and parasitize the host eggs in vegetable crops.

Secondly, egg parasitoids containing egg cards should be tied in the field at least one day prior to adult emergence so that the adults emerging on the following day will get accustomed to the cropping ecosystem and more likely to stay in the field due to the effect of kairomone than the ones released in the form of adult. Further, freshly emerged adults, soon after mating, parasitized more number of host eggs in the field. On the day of emergence, the parasitoid laid 49.8% of its total eggs (Nandihalli & Lee, 1994).

In preliminary investigations in laboratory, cages have showed that a novel release technique of spraying loose parasitized eggs mixed with agar solution was found to be the best among the treatments in which aqueous solutions were used as carriers. In treatments in which loose parasitized eggs were mixed with various solid and aqueous carriers, the per cent of emergence was low (40.5 to 57.1%) compared to 95.0 to 100.0% for release of adults, Tricho bit, Tricho capsules and loose eggs without any carrier. Adult release, sprinkling of loose parasitized eggs mixed with vermiculite and semolina gave significantly higher parasitism if compared to other techniques of release. The results indicated that release of *Trichogramma* can also be tried by mixing with a spray solution (for eg. agar solution) with modification of sprayer nozzle or with solid carriers (for eg. vermiculite). Such techniques will be expected to increase the uptake of this important biological control agent (Jalali et al., 2005).

Field evaluation

A list of egg parasitoids tried against field pests of vegetable crops is furnished in Table 2 and 3. It is observed that *T. chilonis* was extensively used for the control of pests such as *H. armigera*, although no information is available on whether the egg parasitoid released in the field was earlier collected from the same target pest / host plant or not.

Tomato

Of all vegetables, tomato apparently received greater attention in biological control since *H. armigera* could not be managed by chemical control *per se*. Weekly releases of *Trichogramma chilotraeae* Nagaraja on tomato @ 2,50,000 adults ha-^{1} produced about 92% parasitization of *H. armigera* on tomato (Stinner,1977). Similarly, weekly releases of *T. chilonis* at 2,50,000 adults ha^{-1} were found effective against *H. armigera* on tomato and potato (Yadav et al., 1985). Inoculative releases of *T. brasiliensis* in tomato field resulted in 34.6 to 51.3% parasitism of *H. armigera* (Mani and Krishnamoorthy, 1983) and suggested the use egg parasitoid *T. brasiliensis* against fruit borer on tomato (Krishnamoorthy, 1987; Krishnamoorthy & Mani, 1987, 1988, 1993). *Trichogramma brasiliensis,* thus, appears to be of considerable value for the biological control of *H. armigera* on tomato. However, inundative releases of *T. chilonis* also reduced the larval population of *H. armigera* in tomato (Divakar & Pawar, 1987). Later, *T. pretiosum* was also found potential in the control of *H. armigera* under field conditions. Percentage parasitism caused by all four species like *T. exiguum*, *T. chilonis*, *T. perkinsi* and *T. brasiliensis* released against *H. armigera* on tomato in the fields of Himachal Pradesh resulted in 100% parasitism (Kakar et al., 1990). The mean per cent reduction in the larval population of *H. armigera* was 55.9% after releasing 2 exotic egg parasitoids, *T. brasilienisis* and *T. pretiosum* and an egg-larval parasitoid, *Chelonus blackburni* Cameron but increased by 14.3% in fields where parasitoids were not released (Rawat & Pawar, 1993). Release of *T. pretiosum* at 2.5 and 5 lakh adults ha^{-1} reduced the borer damage in tomato to less than 4.0% and 1.09%, respectively, if compared to 12% and 8.92% in the control (Krishnamoorthy & Mani, 1996). The borer damage in tomato could be reduced further by integrating *T. pretiosum* with two rounds of *Ha*NPV spray @ 1 x 10^{9}POB ha^{-1} (Krishnamoorthy & Mani, 1996). *Trichogramma pretiosum* release in tomato resulted in 19.3% borer damage, against 43.9% in control (Mehetre & Salunkhe, 1998). *Trichogramma pretiosum* was released @ 50,000 adults ha^{-1} for release at 7 – 10 days interval against *H. armigera* in tomato at Solan produced 27.8 to 93.4% parasitism in the field (Gupta & Babu, 1998). Four releases of *T. pretiosum* on tomato, each consisting of 50,000 parasitised *Corcyra* eggs, at 10 days intervals provided 58.3, 93.4, 27.8 and 37.5% parasitism, respectively as against 22.2 – 35.0% in control. Five such releases at weekly intervals provided 40 – 45% parasitism (no parasitism in the control), when mean egg density was 0.7 per plant (Gupta & Babu, 1998). Fruit borer, *H. armigera* was kept under control by inundative releases of egg parasitoid *T. pretiosum* at the rate of 2.5 lakh ha^{-1} (Krishnamoorthy, 2003a). From the above study it is clearly observed that *T. pretiosum* is an ideal egg parasitoid to be used against *H. armigera* attacking tomato.

Brinjal

Trichogramma japonicum has been used for the control of brinjal shoot and fruit borer and found that about 28% fruits were damaged in release plot as against 52.5% in control (Sasikala et al., 1999). While *Trichogramma japonicum* has been mainly used for the control of tissue borers on paddy and sugarcane, it is not clear how it could be so effective against brinjal and shoot borer. In such cases, identification of species becomes more critical. Highest yield of Brinjal was obtained in field in which augmentative release of *T. chilonis* was made (Bustamante et al., 1994). Similarly, in India also, trials indicated that *T. chilonis* reduced the fruit borer damage when inundatively released at the rate of 2.5-10 lakh adults ha^{-1} (Raja et al., 1998b, Krishnamoorthy& Mani, 1999b, Jayaraj et al., 2000). The borer damage was 19% when egg parasitoid was released @ 2.5 lakh adults ha^{-1}. But this was further brought down to 10% when rate of release was increased to 5.0 lakh adults ha^{-1} (Krishnamoorthy & Mani, 1999b). Subsequently, effectiveness of the above egg parasitoid was evaluated by different centres at different locations under AICRP on Biological control and reported that the egg parasitoid was capable of controlling the borer more effectively. Tamil Nadu, Orissa and Rajasthan started producing *T. chilonis* for use against fruit borer by the farmers. The borer was kept under excellent control by inundatively releasing more egg parasitoid, spreading right from transplantation to final harvest (4-6 months) at weekly intervals, at the rate of minimum 50 thousand adults ha^{-1}. Release of *T. chilonis* @ 5.0 lakh adults ha-1 was found to be effective against fruit borer (IIHR, 2004a). Krishnamoorthy (2005) suggested integrating the release of egg parasitoid *T. chilonis* with Bt to bring down the borer damage. In a trial where *T. chilonis* and Bt (dipel) were used, the fruit borer damage was 2.5% as against 27.4% in the field in which mass trapping with *Leucinodes* pheromone was alone attempted. *Trichogramma chilonis* alone reduced the borer damage by 80.8% over control, when released at the rate of 5 lakh adults ha^{-1}. While integration of releases of *T. chilonis* with Bt, NSKE 4% and shoot clipping reduced the borer damage by 85.7, 84, 86%, respectively, over control (Ganga visalakhi & Krishnamoorthy, 2005). In yet another trial, *T. chilonis* was alone found capable of bringing down the fruit borer damage to 3.5% (Ganga visalakhi & Krishnamoorthy, 2009). The fruit borer damage was 1.16, 3.42 and 2.3% in three cvs of brinjal namely, black Star (Indo American), Green Long (PHS 909 (Prabha Hybrid Seeds) and Purple round & white Striped (Manjarikota type) MEBS 10 (MYHCO), respectively, in a field demonstration of Bio-intensive management of brinjal pests in 2009, in which *Leucinodes* pheromone trap was placed at the rate of 8 ha^{-1} weekly releases of *T. chilonis* was stared at the rate of 50,000 adults ha^{-1} from 21 days after transplanting and continued up to 20 weeks, besides two rounds of Bt (Dipel 1g/l) were sprayed at 10 days interval when 50% of plants flowered. The fruit borer damage during the same period in other farmer's field (held as control) was 51% (Dr. A. Krishnamoorthy, Personal communication 2009). From the above trials, it was clear that *T. chilonis* releases had the potential to control the fruit borer far better than chemical control. The time of release, distance between two release points in the field, number of adults released, number of releases, integration with other safe methods, etc. are reckoned to play a vital role in reducing the level of fruit borer damage.

Okra

Trichogramma chilonis was used for the control of *H. armigera*, *E. vittella* on okra, and released at fortnightly intervals, which significantly reduced the pest damage in okra and produced fruit yield 20.30t as against 13.06t in control (Raja et al., 1998a). *Trichogramma brasiliensis* and *T. pretiosum* were also evaluated for the control of *H. armigera* on okra (Table 2) but found ineffective in controlling the fruit borer.

Chilli

Fruit borer, *H. armigera* was kept under control by inundative releases of egg parasitoid *T. pretiosum* at the rate of 2.5 lakh ha^{-1} (IIHR, 2004b, Krishnamoorthy, 2003b) (Table 2)

Cabbage

A total of 2, 50,000 adults of *T. bactrae* ha^{-1}, released @ 40,000 –50,000 adults per week ha^{-1}, from transplanting for 6-7 weeks, reduced the DBM infestation by 30% (Krishnamoorthy & Mani, 1999a). Inundative release of the egg parasitoid should therefore be aimed almost right from transplanting time onwards as the greatest damage occurs when the infestation takes place in young plants and that too when it attacks at primordial stage. A total of six releases, @ 50, 000 adults per release week $^{-1}$ ha^{-1}. was recommended for effective control of DBM on cabbage (Krishnamoorthy, 2003c).

The optimum release dosage of *T. bactrae* and its comparative efficacy, both alone and in combination with dichlorvos against diamondback moth (DBM), *Plutella xylostella*, on cabbage has been worked out. The percentage parasitization under different host-parasitoid ratios revealed that the maximum parasitization (83.0%) was in the ratio 100 (eggs):5 (females), which was on par with other higher ratios of 100:10 to 100:20. The release of *T. bactrae* twice (2 and 5 days after DBM moth release) proved as the most effective treatment in significantly reducing the larval population (4.89 larvae per plant) in comparison to two sprays of 0.05% dichlorvos (14.54 larvae per plant). The results indicated the efficacy of *T. bactrae* in suppressing DBM on cabbage and calls for further evaluation in field trials (Singh et al., 2004). An exotic egg parasitoid *T. brassicae* has been evaluated at IIHR against DBM on cabbage in Bangalore. In cabbage, where *T. brassicae* was inundatively released at 6 lakh adults ha^{-1} showed very less larval population (PDBC, 2009). This parasitoid has also performed very well at Coimbatore, Rahuri, Jorhat and Srinagar in the control of DBM when released at 3 lakh adults ha^{-1}. In fact, *T. chilonis* also equally controlled DBM on par with *T. brassicae* in the above locations (PDBC, 2009).

Integration

Integrated control strategies were evaluated against tomato fruit borer, *H. armigera* with egg parasitoid *T. pretiosum* and insect pathogen *Ha*NPV (Krishnamoorthy et al., 1999a) and with safe insecticides (Krishnamoorthy, 2003a.). All these strategies were found more effective than any single measure of control (Krishnamoorthy & Mani, 2000). Similarly integrated control strategy was evaluated against brinjal shoot and fruit borer under coastal agroclimatic conditions of Bhubaneswar, Orissa, with eight treatments comprising 6 releases of *Trichogramma chilonis* at 50,000 adults at 15 days interval starting from 30 days after transplanting (DAT) (T1); T1+Multineem at 3 ml/l at 10 days interval from 30 DAT (T2); Multineem at 3 ml/l alone, 6 sprays starting from 30 DAT (T3); neem seed kernel extract (NSKE) at 4% (spray once) in 10 days starting from 30 DAT (T4); 5 sprays of cypermethrin at 30 g/ha, starting from

30 DAT (T5); hand clipping+2-m Nylon net barrier (T6); soil application of neem cake at 50 g/plant at planting and repeated 2 more times at 30 days interval; and a control (T8). The mean damage by the borer in the control plots was 25.37 and 63.49% on shoot and fruit basis, respectively. The release of *T. chilonis* alone did not show significant impact on the pest damage whereas *T. chilonis* combined with Multineem recorded 13.41 and 45.96% shoot and fruit damage, respectively (Singh et al., 2005). It is possible that the volatiles from the neem products might have repelled the egg parasitoid from their activity and thereby reduced parasitism levels in sole *T. chilonis* release plots.

Two field experiments were conducted in okra to test the efficacy of the egg parasitoid *Trichogramma chilonis* (TC), besides neem oil (NO), Palmarosa oil (PRO), neem seed kernel extract (NSKE) and endosulfan at the varying economic threshold levels to control the fruit borers*, Earias vittella* Fabricius and *E. insulana* Boisduval damage. In both experiments, the cost:benefit ratio was the maximum in endosulfan treatment and was the minimum as for the release of *T. chilonis* at 2.5% fruit damage (Sumathi & Balasubramanian, 2002).

Periodic releases of *T. chilonis*, *Telenomus remus* and *Tetrastichus ayyari* and predator *Brinckochrysa (Chrysopa) scelestes* banks reduced the pest by 60% and increased yields by 12% (Ansari et al., 1992). The egg parasitoids may not be released along with general predators (such as green lace wing) as the latter may attack the brinjaleggs. Third instar nymphs of *B. scelestes* readily preyed on eggs of *H. armigera* parasitized by *T. chilonis, E. vittella* brinjaleggs by *T. achaeae* or *S. litura* brinjaleggs by *Telenomus remus* Nixon. The number of preyed parasitized eggs increased as the age of the brinjaleggs increased. These data indicated that either the egg parasitoid or the predator, but not both together, should be used for the control of above pests (Krishnamoorthy & Mani, 1985b). DBM on cabbage was controlled by egg parasitoid *T. bactrae* to the tune of 39.4 to 46.9% when trap crop mustard was raised all along the border of cabbage field. The low reduction was attributed to low population of DBM both in treatment and control (Krishnamoorthy et al., 2002). Egg parasitoids, *T. bactrae*, can be integrated with Bt for successful control of not only DBM but also other lepidopteran pests on cabbage. Similarly, trials have shown very good results when the egg parasitoid *T. bactrae* was combined with NSP 4% for the control of DBM and other pests on cabbage (IIHR, 2004b). DBM larval population on cabbage in which *T. brassicae* was inundatively released at the rate of 6 lakh adults ha^{-1} (in the presence of maize grown as border crop) had very less population of 1.8 larvae/plant as against in control recording 4.6larvae/ plant (PDBC, 2009).

Safety of pesticides to egg parasitoids

The effect of cypermethrin (0.01%), decamethrin (0.0025%), fenvalerate (0.01%) and permethrin (0.00125%) on the egg parasitoid *T. brasiliensis* was tested under laboratory conditions. Cypermethrin resulted in 75.45% parasitism of host eggs by *T. brasiliensis* and 88.64% emergence, compared with 94.42% parasitism and 100% emergence for untreated hosts (Gupta et al., 1988). The residual toxicity of three insecticides *viz*., quanlphos, methomyl and alpha cypermethrin on *T. chilonis* revealed that alpha cypermehtirn was the safest for the parasitoid. These parasitoids could be safely released 3, 4 and 5 days after crop has been sprayed with alpha-cypermehtirn, methomyl and quinalphos respectively (Samanta et al*.*, 1998). Parathion methyl was the most toxic chemical, followed by quinalphos, whereas phosphamidon was the least toxic to the pupal stages of *T. chilonis*. Carbaryl, monocrotophos and endosulfan had intermediate toxicity (Mandal & Somchoudhury, 1992).

Among botanicals, nearly 10 neem products were evaluated against *T. chilonis* for their safety. All products inflicted adult mortality ranging from 72.4% (Replin) to 30.9 % (neem rich II). However, the adults could be able to parasitize 92.9 to 99.6% of the eggs offered. Parasitoid emergence was unaffected by theses products (Singh & Jalali, 1994)

Integration of egg parasitoids with other methods of control

Treatments viz., endosulfan (0.07%), neem oil (2 or 4%) and *Trichogramma chilonis* decreased the pest damage by 49.73% if compared to the untreated control (Raja et al. 1998a). Combined use of egg parasitoid, *T. pretiosum* and B. t. at 1.0 or 1.5 kg formulated material / ha was more effective in suppression of *H. armigera* on tomato (Gupta et al., 1998).

Future strategy

Trichogramma chilonis is prevalent everywhere but the species collected from one cropping system may not work very well in another cropping system. Therefore, selection of the strain /ecotype plays a crucial role. For example: six ecotypes of *Trichogramma chilonis,* collected from 6 different parts of Tamil Nadu, were compared with the laboratory strain of the same species (Coimbatore). All the ecotypes were significantly superior to the laboratory strain in parasitizing the eggs of *C. cephalonica*, *H. armigera* and *Spodoptera litura* and they have showed a distinct preference for *H. armigera* eggs (Kumar et al., 1994). But tritrophic interactions should be studied before using the egg parasitoids in a target cropping system.

An ecotype of *T. chilonis* (collected from Palladam, Tamil Nadu) was able to withstand starvation for a maximum of 6.86 days (Kumar et al., 1994). This is a good trait, which should be exploited for incorporation in other strains of *T.* chilonis. This will help in mass production and shipment of emerged adults. The effects of 2-tridecanone and 2- undecanone / glandular trichome – based pest resistance of tomato on the behavior of the parasitoids *Trichogramma pretiosum* and *Telenomus sphingis* in the laboratory showed that the parasitism of eggs of *Heliothis zea* (Fab.) by *T. pretiosum* was significantly lower on plant lines with methyl ketone (4.0 – 5.8%) than those without methyl ketone (65.4 – 85.8%). The effects of methyl ketones included a higher percentage of parasitoid flying off discs before reaching the edge, entrapment of parasitoid in trichome exudates, etc. In tomato, genotypes with varying densities of type VI glandular trichomes (3.1 – 9.2 mm^2) but without methyl ketones in the trichome tips, such effects were not observed. As far as *T. sphingis* concerned, the percentage of wasps initiating flight was directly correlated with trichome density among number of ketones. *Telenomus sphingis* was able to free itself from entanglement unlike trichogrammatids. It is concluded that a significant proportion of the reduction of parasitism by both parasitoids was attributed to the effects of methyl ketones (Kashyap et al., 1991a, b).

A species of *Trichogrammatoidea* near *T. guamensis* Nagaraja was found to be an effective egg parasitoid of Earias spp. on cotton in the Punjab, India, being widely distributed and giving up to 46.6% parasitism (Varma et al., 1980). Eggs of cotton pests *E. vittella* and *H. amigera* were brinjaleggsby 9 species of trichogrammatids up to 89.39 – 97.30% and 88.48 – 97.29%, respectively (Hanumanna et al., 1984). Therefore, these trichogrammatids could play a better role in the control of *E. vittella* and *H. armigera* which occurs regularly on Okra and Cotton. To a certain extent, the egg parasitoid collected from *E. vittella* and *H. armigera* (cotton as host plant) may do well in the okra ecosystem for the control of the above two pests. When okra was grown as trap crop in cotton ecosystem, the eggs of *Earias* spp. and *H. armigera* on okra were naturally parasitized by *Trichogramma achaeae* and *T. chilonis* by 14.87% and 4.84%, respectively (Naganagoud & Thontadarya, 1984). Among seven important lepidopterous crop pests evaluated in the laboratory as for suitability to *Trichogramma pretiosum* and *T. australicum*, *Exelastis atomosa* was the most suitable host for both species, based on the parasitization ability, rate of emergence and duration of the life cycle of the parasitoids.

Eggs of *Agrius convolvuli* (L.) is an occasional pest of Sweet potato. Eggs of *A. convolvuli* are frequently laid on *Colocasia antiquorum* and *Clerodendron fragrans var. pleniflorum*, though no feeding damage has been observed. But, the eggs on these crops were parasitized by trichogrammatids(*T. chilonis* (= *australicum*) and *Telenomus* to the tune of 63.9% (Nagarkatti, 1973). Therefore, it is suggested that the above shrubs could be planted in and around sweet potato fields to facilitate the maintenance of reservoirs of the parasitoid.

Up to 49 individuals (generally progeny of one female) of *Trichogramma* were found to have successfully complete their development in one egg of *Agrius (*Nagarkatti, 1973). *T. chilonis* stored for 7 days at 8 – 10°C in the refrigerator was successfully brinjalfor 23 days without adversely affecting their emergence and parasitization efficiency (Khosa & Brar, 2000). Storing of excess of egg parasitoids for some period will help in regulating the inundative releases when required.

T. chilonis could not survive above 38°C under field condition and therefore it was suggested to release in tomato for the control of fruit borer after the onset of monsoons when the temperature drops below 35°C in Gujarat (Yadav et al., 1985). *T. chilonis*, *T. brasiliensis* and *T. pretiosum* were released for the control of *H. armigera* on several crops and the greatest reduction in the larval population (92.4%) was observed on tomato (Divakar & Pawar, 1987).

Conservation

Anagrus flaveolus and *Stethynium triclavatum* were effective egg parasitoids of *Empoasca* sp. *Anagrus* sp., *A. flaveolus*, *Arescon euochi* and *Oligosita* sp. parasitized *Amrasca biguttula biguttula*. In the field, *A. flaveolus* was active throughout the year on various host plants with peaks of activity during July and October-November. *Stethynium triclavatum* and an unidentified parasitoid were active during September (Singh et al., 1993). Many of these parasitoids were only reported from the jassids. No concentered efforts have been made to mass produce the parasitoids and release them in the field. Therefore, attempts should at least be made to conserve these parasitoids by judiciously applying safe pesticides.

Scope

Under laboratory conditions, *T. exiguum* caused the highest parasitism (100%) on *H. armigera*, followed by *T. brasiliensis* (98%), *T. chilonis* and *T. perkensi* (90%) and *T. chilonis* (=*minutum*) (70%). *Trichogramma exiguum* and *T. chilonis* completed life cycle in 6 – 19 days producing 120 – 150 adults, but no adult parasitoids emerged in the other species. Percentage parasitism caused by all the 5 species against *H. armigera* on tomato in the field was 100 (Kakar et al., 1990).

Periodic releases of large numbers of egg parasitoids could help in suppressing populations of *S. litura*. There is considerable scope for increased attention to the role of natural enemies as components of IPM programmes for controlling *S. litura*. *T. chilonis* is able to search for *S. litura* eggs on most of the crops, but it may not be suitable for field releases as it is unable to parasitize multilayered eggs (Singh & Jalali, 1994). *Trichogramma chilonis* possessed detectable level of radioactive phosphorous when it parasitized the eggs of *Corcyra* fed on sorghum grains treated with radioactive phosphorous. Such experiments show the scope to study the dispersal behavior and population stability in the released area.

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