EGG PARASITOIDS – A PROMISING BIOCONTROL AGENT IN INSECT PEST MANAGEMENT

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ABSTRACT

Pests are thought to be responsible for over 70% of global losses in important crops like cotton, pulses, rice, and vegetables, which adds up to US$400 billion. Farmers usually employ additional chemical insecticides to get around this. Insect resistance to pesticides has increased as a result, and toxins have accumulated in the food chain. Due to the early eradication of the pests' natural enemies, it has also increased the pest infestation in the following crop. IPM is crucial at this point, and many farmers believe it is urgently needed. The usage of egg parasitoids is one of them. At the field level, this review paper will clarify the extent, significance, advantages, and difficulties.

Key words: chemical pesticides, insect resistance, food chain, egg parasitoids

I. INTRODUCTION

Parasitoids are a diverse collection of insects that provide biological control of pests in greenhouses, gardens, and agricultural areas. An organism that becomes a parasite spends its larval development on or inside a host, which is another organism. The host is eventually killed by the larval parasitoid as it grows and consumes it entirely (Mills, 2009). Parasitoids cause their host to die, unlike other parasites like lice or ticks that do not necessarily do so. The adult parasitoid leaves the host to find a spouse and a new host to lay her eggs on. To target, eat, and avoid the host's immune system, a parasitoid must have extremely precise strategies as it develops in or on a host. Because of their great degree of specialization, most parasitoids only target one or a few closely related species.

Herbivorous insect egg parasitoids locate eggs to parasitize by reacting with short- and long-range chemical cues produced by hosts and host plants (Vinson, 1998; Fatouros, 2008). By using behavioural research to identify the volatile substances that attract egg parasitoids, herbivorous pests can be biologically managed by modifying parasitoid behaviour in the field. However, a given cue's timing and method of usage vary over an individual's life as well as at and below the species level. Future research should expand their taxonomic scope to examine variations in the usage of chemical cues in more dynamic, natural contexts. Separating the underlying genetics and improving biological control will be made easier with a more thorough understanding of the range of host-finding tactics used by egg parasitoids. The most significant natural enemies of the eggs of predatory Heteroptera are parasitoids, if the percentage of literature devoted to a particular type of natural enemies is any guide. There are several studies of parasitism rates of different species in different circumstances, and the majority of these parasitoids belong to the Scelionidae and Mymaridae (Hymenoptera) (McPherson, 1982; Lattin, 1989; Javahery, 1994; Jackson, 2003; Torres and Ruberson, 2006). Predatory animals have developed a variety of defense mechanisms against parasitism, and under certain situations, their rates of egg parasitism can surpass 100%. Egg parasitoids, which have been employed in the biological control of insect pests, are found in the six groups of the parasitic Hymenoptera. While the remaining four families—Elasmidae, Encyrtidae, Eulophidae, and Platygastridae—also contain egg parasitoid species, three of these families—Mymaridae, Scelionidae, and Trichogrammatidae—are exclusively egg parasitoids.

Different families of egg parasitoids:

***Trichogrammatidae*:**

They are fundamental endoparasitoids and one of the best-known groups of Chalcidoidea. Their compact body shape without a mesosomal-metasomal constriction, three-segmented (trimerous) tarsi, fewer antennal segments, forewing that often contains setae grouped in separate rows, and absent or greatly decreased post-marginal vein are characteristics that set them apart. Currently, there are 90 genera and about 800 species in the Trichogrammatidae family. Although most of the genera in the family are small and have known limited ranges, the larger genera are found all over the world.

Mymaridae (Fairy flies):

These parasitoids have non-metallic bodies, are small (usually less than 1 mm), and are usually solitary but can sometimes be gregarious at times. Mymaridae developed early in the history of the Apocrita (Yoshimoto, 1975). Huber (1986) and Burks (1979) assert that all species start out as internal parasitoids of insect eggs. Auchenorrhyncha, whose eggs are concealed in soil, beneath bark, and inside plant tissues, are preferred by larvae, which are often solitary. Within the host egg, pupation occurs. For some species, biological control programs have been successful (Clausen, 1978).

Scelionidae:

The Scelionidae is a very large and extensive group, with 176 genera and over 3000 species recorded. parasitoids of spiders and insect eggs. These insects are little to very small. Although they rarely have 7–10 segments, antennae are geniculate, containing 11–12 segments. Stigma and sub-marginal veins are always linked to forewing, and post-marginal veins are often linked to it as well.

Elasmidae:

There are about 205 species in the entire planet. One important figure is the four-segmented tarsi. Medially, the propodeum is extended. They resemble really rough flies. Although some species are parasitoids of Polistes spp. larvae, they are primarily parasitoids or hyperparasitoids of Lepidoptera larvae.

Encyrtidae:

The large family Encyrtidae contains over 455 genera and 3710 species of parasitic wasps. While some species have a varied life history (attacking eggs, attacking larvae, being hyperparasites, and developing as tick parasitoids), the majority of larvae are primary parasitoids on Hemiptera, but they also target other hosts. They are commonly found in practically all of the world's environments and are essential biological control agents.

Eulophidae:

330 genera and well over 3,000 species make up this large family (Gauld and Bolton, 1988). Males of several species have pectinate antennae, their tarsi are four-segmented, their mesopleuron has a well-developed groove for receiving the middle femur, and they are metallic in colour with faint sclerotization.

Platygastridae:

These tiny, shiny black insects have thin wing venation that makes them resemble chalcids. Ten segments make up the antennae, which are frequently joined quite low on the face, next to the clypeus. Most species parasitize larvae of the Cecidomyiidae family. *Platygaster hiemalis* Forbes has been successfully used to biologically manage the Hessian fly. A single egg can produce up to 20 offspring in certain species that demonstrate polyembryony.

***Trichogramma* spp.:**

These tiny wasps are endoparasites of lepidopteran eggs. The main advantage of Trichogramma species as biological control agents is their small size; adult egg parasitoids are just 0.3 mm length, which makes them almost invisible to the untrained eye. These species kill the developing moth embryo before it hatches by putting their eggs in lepidopteran eggs, so avoiding the dangerous larval stage. After eating the contents of the moth egg and pupates, the parasitoid larva emerges as an adult wasp after 7–14 days. A single female wasp can parasitize up to 50 eggs in their 3–14 day adult life cycle. Adult parasitoids quickly mate after they emerge.

Some important *Trichogramma* sp.:

Table 1: Different species of egg parasitoids used for parasitization	
Species of egg parasitoids	Used for parasitization of host eggs
Trichogramma chilonis Ishii	Sugarcane borers (*Chilo infuscatellus, Chilo sacchariphagus* indicus, *Chilo auricilius, Acigona steniellus*); Cotton bollworms (*Helicoverpa armigera, Pectinophora gossypiella* and *Earias* Spp.); Maize stem borer (*Chilo partellus*); Diamond back moth (*Plutella xylostella*); Tomato fruit borer (*Helicoverpa armigera*)
Trichogramma japonicum Ashmead	Top shoot borer of sugarcane (*Scirpophaga excerptalis*), Paddy stem borer (*Scirpophaga incertulus*)
Trichogramma achaeae Nagaraja and Nagarkatti	Cotton bollworms and Okra fruit borer (*Helicoverpa armigera*)
Trichogramma pretiosum Riley	Tomato fruit borer (*Helicoverpa armigera*)
Trichogramma dendrolimi Matsumara	Lepidopteran pests on cruciferous crops
Trichogramma evanescens Westwood	*Lepidopteran pests (Agrotis ipsilon, Achaea Janata, Corcyra cephalonica, Etiella zinckenella, Helicoverpa armigera, Heliothis virescens, Spodoptera littoralis, Plutella xylostella* etc.)
Trichogramma mwanzai Schulten and Feijen	*Busseola fusca, Chilo partellus, Eldana saccharina, Ephestia kuehniella,* *Sitotroga cerealella*
Trichogrammatoidea armigera Nagaraja	Lepidopteran pests (*Achaea Janata, Corcyra cephalonica, Etiella zinckenella, Helicoverpa armigera, Heliothis virescens, Spodoptera littoralis, Plutella xylostella*)
Trichogrammatoidea bactrae Nagaraja	Lepidopteran pests (*Agrotis ipsilon, Achaea Janata, Corcyra cephalonica, Etiella zinckenella, Helicoverpa armigera, Heliothis virescens, Spodoptera littoralis, Plutella xylostella* etc.)
Trichogramma brassicae Bezdenko	Diamondback moth (*Plutella xylostella*) and Cabbage butterfly (*Pieris brassicae*) on cabbage and cauliflower
Trichogramma embryophagum Hartig	Apple Codling moth (*Cydia pomonella*)
Trissolcus basalis Wollaston	Green stink bug (*Nezara viridula*), Red banded stink bug (*Piezodorus guildinii*)
Anagrus giraulti Crawford	Wheel bug (*Arilus cristatus*), Beet leafhopper (*Circulifer tenellus*)
Anagrus flaveolus Waterhouse	Brown plant hopper (*Nilaparvata lugens*), Maize leaf hopper (*Dalbulus maidis*)
Anaphes fuscipennis Haliday	Clover leaf weevil (*Hypera zoilus*), Alfalfa root weevil (*Sitona discoideus*)
Telenomus remus Nixon	Tobacco leaf eating caterpillar (*Spodoptera litura*)
(Source: Anonymous, 2019)	

Mass production of *Trichogramma* spp.

Schematic representation of mass rearing procedure of *Trichogramma* spp. Through mass production of *Corcyra* cephalonica laboratory host has been given by Vijaykumar (2009) is as following:

1) Place 2.5 kg of fresh, cleaned, insecticide-free bajra, sorghum, maize, or paddy grains in plastic trays or Corcyra rearing cages (one set used for 100 days) after sterilizing them for 30 minutes at 100 °C.

2) Add 100 grams of groundnut kernel powder as a protein source.
3) Including 0.01 sulphur as a pesticide, 0.05 g of streptomycin sulphate as an antibiotic, and 5 g of yeast pills as a food supplement.
4) Putting one cc of fresh, viable Corcyra eggs in each cage or tray. keeping the culture at 26 °C. After 40–45 days, the adult moth begins to emerge.
5) Regular collection of adult moths manually and mechanically using vacuum cleaner.
6) Allow adult moths in fecundity cage used for three days supplementing with food swab impregnating honey 15%, water and vitamin E (2 caps).
7) Daily collection of *Corcyra* eggs.

To remove dust particles or separate the scale admixture in eggs mechanically using a motorized egg separator, the eggs are passed through 15, 30, and 40 mesh sieves and then run down a slope of paper.

8) Harvest fresh eggs.
9) Storage of *Corcyra* eggs at 10 °C up to seven days.
   Newly gathered Corcyra eggs are exposed to a 30-watt UV tube light for 45 minutes. The eggs are then pasted onto six pieces of 15 × 10 cm "Tricho" cards (12 × 3 cm respectively).
10) Introduction of single egg card inside parasitization chamber along with nucleus culture of *Trichogramma* strain maintaining in ratio of one female to 30 eggs for effective parasitization.
11) Parasitization takes place within a week time.

14) A single card produces about 12,000 mature *Trichogramma*.

Preparation of Trichocards:

a. Tricho cards are created when *Trichogramma* spp. parasitize one cc egg of Corcyra cephalonica in a lab setting. The eggs are evenly scattered and adhered to a 15 cm × 10 cm card. Twelve demarcations (stamps) are on the card.
b. Using a tea strainer, evenly distribute the cleaned eggs in a single layer after applying gum to the card.
c. Once the card has had enough time to air dry beneath the fan, the excess eggs pasted are carefully brushed off with a shoe brush.
d. To kill the embryo, expose the eggs to a UV lamp for 30 minutes (the current market price for a UV lamp is Rs. 1,121).
e. In a polythene bag, place a UV-treated "Trichocard" and a nucleus card in a 6:1 ratio (6 Corcyra egg cards: 1 Trichogramma nucleus card). Then, use a cotton swab soaked in 50% honey and vitamin E.
f. After a day, take the Tricho cards out. The Corcyra eggs turn black on the fourth day, which is a sign that the eggs are parasitized.

Release the Tricho cards into the fields whenever a minimum of 5% adult emergence (pharate stage) is observed. Before each release, snip 12 or 16 trichomes and staple them to the underside of the plant's leaf in the morning or evening.

g. Trichocards can be kept in a refrigerator or freezer at 10 degrees Celsius for up to 21 days after the fourth or fifth day. We should release Trichocards into the field right away if we won't be keeping them in the refrigerator.

Precautions for releasing *Trichogramma* sp:

1) To help the user, the cards should include the date of the emergence. To keep the cards out of direct sunlight, attach them to the inside of the leaves. To prevent predation, the cards should be stapled in the morning and right before emergence.
2) Refrain from using pesticides in areas where *Trichogramma* are present. Use safer and selective insecticides as necessary. Make sure to use pesticides at least 15 days prior to or following the

release of *Trichogramma*.

3) Control failures may arise from mass-reared *Trichogramma* of poor quality. The mass growing process's artificial settings may favour genetic alterations that lessen Trichogramma's usefulness in the field.
4) The absence of plants, congestion and interference, quick generation time, failure to rejuvenate genetic stock, and raising many generations on unnatural host eggs are examples of such rearing settings.
5) Growers and pest experts are unable to identify low-quality Trichogramma before release, with the exception of evident issues such wing abnormalities or lack of adult emergence. Maintaining the ideal qualities required for successful performance in the field is the responsibility of commercial providers.
6) Individuals from a stock culture kept on the natural or target host should be periodically added to production colonies. To ensure that they fall within permissible bounds, suppliers should additionally evaluate the percentage of host egg parasitization, adult emergence, and the sex ratio of emerged adults.
7) A sex ratio of 1 to 1.5 females per male, 90±5 percent adult emergence, and 95±5 percent egg parasitization are standards for established cultures on Corcyra.

***Trichogramma*: A Boon or a Bane to Farmers?**

Boon of *Trichogramma*:

a. Natural Pest Control: *Trichogramma* provides an environmentally friendly alternative to chemical pesticides. By parasitizing pest eggs, they reduce pest populations without posing a threat to the environment, beneficial insects, or people. This is advantageous for integrated pest management (IPM) systems.

2) Decreased Chemical Usage: *Trichogramma* can significantly lower the need for chemical pesticides, leading to safer food production, a decrease in pesticide resistance, and reduced environmental pollution.
3) Cost-Effective: While releasing *Trichogramma* may first appear costly, the long-term benefits (such a reduction in the need for pesticides) make it an economical decision. It can be very useful in organic farming, where chemical pesticides are not allowed.
4) Targeting Specificity: *Trichogramma* have a high level of host pest specificity. They do not harm other non-target species, unlike broad-spectrum chemical pesticides, which can kill a wide range of insects, including beneficial ones.
5) Sustainability: *Trichogramma* is a natural predator that complements sustainable agricultural methods by assisting in preserving the ecosystem's delicate balance of natural enemies and pests.

Bane of *Trichogramma*:

1) Effectiveness Restricted by Pest Type: While some pests may react favourably to trichomonia, not all pests may do so. If a farmer's crop is attacked by pests that are not Trichogramma-susceptible, its use may be limited.
2) Require Proper Management: Trichogramma's effectiveness is influenced by environmental conditions, pest monitoring, and treatment timing. Inadequate monitoring or incorrect release might lead to inefficient pest management.
3) Cost of Mass Production: Economic viability over the long run However, producing Trichogramma in sufficient quantities for widespread use could be expensive. Small-scale farmers could find it challenging to pay the required sum.

a. Potential Resistance: Pests may eventually develop a resistance to Trichogramma if the same species is used frequently. Rotating biological control agents is necessary to prevent this.

4) Narrow Host Range: *Trichogramma* exclusively targets the egg stages of certain pests, thus if the insect population shifts to a new life stage, the wasp won't be effective. Trichogramma is generally advantageous to farmers, particularly those looking for environmentally friendly, sustainable substitutes for chemical pest management. Its advantages in reducing chemical use, promoting biodiversity, and providing targeted pest control make it a valuable tool in integrated pest management. However, its effectiveness depends on the kind of pests involved, how it is applied, and how often it is monitored. There may not be a single answer that suits everyone, and successful management is essential. Therefore, farmers should carefully evaluate whether Trichogramma is suitable for their specific needs, crop kinds, and environmental conditions.

***Trichogramma* efficacy at the field level:** Among the factors influencing Trichogramma's efficacy at the field level are the kind of pest being targeted, the surrounding environment, and the success of the biological control method. Even though *Trichogramma* has shown great promise in lab and controlled environments, its efficacy varies in the field. The following are important factors to take into account when assessing Trichogramma's performance in field settings:

1. Pest Species and Life Cycle :
   1) Target Pest: *Trichogramma* is more effective against pest species whose eggs are susceptible to parasitism. This includes maize stem borer, cotton bollworm, and a number of lepidopteran pests. However, if the pest does not generate enough eggs to maintain Trichogramma parasitism or if it produces multiple generations in a single growing season, its efficacy may be limited.
   2) Synchronization of the Life Cycle: *Trichogramma* must be released at the appropriate moment, usually when the pest eggs are vulnerable. The biological control agents might not work if the *Trichogramma* discharge does not coincide with the pest's egg-laying season.
2. **Release Strategy and Timing:**
   1) Appropriate Timing: *Trichogramma* releases need to be scheduled with precision. If Trichogramma is released too early or too late in the insect's life cycle, it could not be able to limit the population of the pest. Ideally, releases should occur during the egg-laying season of the target pests.
   2) Multiple Releases: To provide continuous pest control throughout the crop's growing season, in some circumstances, multiple *Trichogramma* releases are necessary. This could lead to increased costs and labour requirements for farmers.
3. **Environmental Conditions:**
   1) Temperature and Humidity: *Trichogramma* activity and parasitism rates are influenced by the weather. High temperatures, wetness, or extreme humidity can all affect Trichogramma's capacity to endure and thrive in the field. Climates that are warm, dry, and steady are generally the best.
      a. Habitat Suitability: *Trichogramma* may have less success in environments where natural enemies such as parasitoids and predators outcompete or attack wasps. Furthermore, monocultures with fewer plant species may decrease the overall effectiveness of biological management by decreasing the diversity of conditions that support *Trichogramma*.
4. **Pest Density:**

   High Pest Populations: *Trichogramma* may have trouble controlling pests when their numbers are very high. *Trichogramma* usually thrives in regions with moderate insect populations, but it may require many releases in fields with severe infestations.

Field Size and insect Spread: In larger fields or areas with unpredictable insect populations, Trichogramma might not be evenly distributed, which would reduce its efficacy. Smaller or more limited infestations respond better to it.

5. **Resistance Development:**

Pest Resistance: Although it is rare, pests may eventually develop a resistance to *Trichogramma*. If one *Trichogramma* species is used for long periods of time without being rotated with other biocontrol agents, this is more likely to happen. Populations of resistant pests may reduce the efficacy of the biological management strategy.

6. **Farmer Management and Monitoring :**

Monitoring and Assessment: Farmers must continuously monitor the pest population to determine when and how much *Trichogramma* should be injected. Insufficient pest monitoring may result in improperly timed discharges, which could reduce the overall efficacy of the biological control method.

Farmer Expertise: Successful field deployment of *Trichogramma* necessitates a certain degree of knowledge and proficiency. This means understanding the pest's life cycle, figuring out the right release rate, and interpreting field findings.

7. **Cost vs. Benefit:**

2) Cost-Effectiveness: *Trichogramma* may reduce the need for traditional pesticides, but small-scale farmers may find the initial cost prohibitive, especially if it is often discharged and generated in big amounts. Long-term benefits like higher agricultural yields and less pesticide residue, however, might offset the cost.

Farmers may be reluctant to use egg parasitoids on a large scale for several reasons:

2) Cost and Availability: The production and distribution of egg parasitoids can be expensive. The cost of acquiring parasitoids and organizing their release might be too expensive for farmers, particularly those who are small-scale or have limited incomes.
3) Effectiveness Issues: Egg parasitoids may not always be effective in controlling pests. Among the factors influencing their success are the density of insect populations, the release time, and environmental conditions. Farmers may be reluctant to invest in a biological control method that doesn't yield consistent results.
4) Compatibility with Other Control Methods: Farmers commonly use a variety of insect control methods, including chemical pesticides. Pesticides may not work well with chemical treatments because they can harm or kill egg parasitoids, reducing their effectiveness.
5) Knowledge Gaps: Many farmers may not fully comprehend the biology and use of egg parasitoids, which could hinder their adoption. If farmers are not adequately informed and encouraged, they may be hesitant to undertake a new and unfamiliar practice.
6) Unpredictability of Long-Term Results: There may be concerns about the long-term ecological impact of bringing egg parasitoids into a region. Unexpected consequences, such the parasitoids spreading or disrupting the local ecology, can worry some farmers.
7) Practical Difficulties: Choosing when and how much parasitoids to use, as well as managing the logistics of monitoring pest populations, may be challenging. For large-scale farms, managing these problems effectively may be challenging.

II. CONCLUSION

Of all the egg parasitoids used for pest control, *Trichogramma* species are the most widely used and exploited globally. Trichogramma's main species, *T. chilonis*, *T. japonicum*, *T. pretiosum*, and *T. achaeae*, are effective against a range of pests, including the cotton boll worm complex, the yellow stem borer of rice, the shoot and fruit borer of brinjal, the early shoot borer and internode borer of sugarcane, and others. The weather, crop, host, predation, pesticide use, and parasitoid quality are some of the many variables that affect the field release. It can be used to control insect pests in conjunction with other IPM elements. Before the invention of synthetic pesticides, India used natural biological control.

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