Eulophid Parasitoids (Hymenoptera: Eulophidae) in biological control: diversity, applications, and future prospects

Mohd Majid Jamali[1], Shafaat Anwer[1], Saba Bano[1] and Ahmad Faraz[2*]

[1] Department of Zoology, Shibli National College, Azamgarh, Uttar Pradesh, India

[2] Department of Botany, Shibli National College, Azamgarh, Uttar Pradesh, India

*Corresponding author: Ahmad Faraz

Received 20 Aug 2025; Accepted 24 Sep 2025; Published 7 Oct 2025

DOI: https://doi.org/10.64171/JAE.5.4.11-15

Abstract

One of the most diverse groups of parasitoids is the Eulophid wasp (Hymenoptera: Eulophidae), with over 6,000 species described across four subfamilies. These wasps target major pests in agriculture and forestry, including Lepidoptera, Diptera, Coleoptera, and Hemiptera, and play a key role in Integrated Pest Management (IPM). They are used in various biological control programs, such as classical, augmentative, and conservation, with many documented successes. This review compiles the current knowledge on Eulophid taxonomy, diversity, ecology, and pest control, while highlighting advances in molecular tools, mass-rearing techniques, and their integration with other natural enemies. It also discusses challenges such as non-target effects, climate change, and taxonomic issues, along with research priorities for enhancing their use in sustainable pest management.

Keywords: Parasitoid wasps, Eulophidae, Biological control, Integrated pest management, Parasitoid diversity

Introduction

Parasitoid wasps play a crucial role in modern agriculture, thanks to their ability to control pest populations by developing inside or on their hosts, ultimately killing them (LaSalle & Gauld, 1993) [34]. Their high reproductive potential, host specificity, and adaptability make them an ideal choice for classical and augmentative biological control (Clausen, 1978) [7]. Within the parasitoid family, Eulophidae stands out as particularly important, with over 6,000 species identified worldwide across four subfamilies: Eulophinae, Entedoninae, Euderinae, and Tetrastichinae (Noyes, 2019) [40].

These insects attack a wide variety of hosts, including Lepidoptera, Diptera, Coleoptera, and Hemiptera, and target their eggs, larvae, and pupae. Their flexibility and track record in controlling pests make them crucial for sustainable pest management, especially given the limitations of chemical control (Delrio *et al*., 2005) [11].

Taxonomy and diversity of Eulophidae

There are around 6,000 known species of Eulophidae, divided into 324 genera (Noyes, 2019) [40]. These species are generally small, measuring 0.5-5 mm, and are characterized by simple wing patterns, unique antennal features, and specialized egg-laying structures. They exhibit great diversity in their lifestyles, ranging from solitary to social and from outside to inside parasitism, with some even acting as secondary parasites (LaSalle & Gauld, 1993) [34]. This range of ecological and physical variations makes them adaptable and practical in various farming systems.

Ecological role and target pest groups

Eulophids parasitize key agricultural and forestry pests, including:

- Lepidoptera: leaf miners, borers, and defoliators (El-Heneidy *et al*., 1990) [15].
- Diptera: leaf miners (Rauf *et al*., 2000) [43].
- Coleoptera: beetle larvae and borers (Haynes & Gage, 1981; Evans & Gage, 2006) [26, 16].
- Hemiptera: psyllids and scale insects (Chien & Chu, 1996; Prinsloo, 1980) [6, 41].

For example, *Tetrastichus planipennisi* is a specialist that effectively controls the emerald ash borer (*Agrilus planipennis*) (Bauer *et al*., 2008; Duan *et al*., 2012) [2,13], while *Diglyphus isaea* is a generalist leaf-miner parasitoid widely used in greenhouse IPM (Murphy & LaSalle, 1999) [39].

Classical biological control successes

Eulophids have contributed significantly to classical biological control programs worldwide.

Table 1: Selected examples of successful classical biocontrol using Eulophid parasitoids

Parasitoid species	Target pest (host)	Life stage attacked	Location	Ref.
Tetrastichus planipennisi	Emerald ash borer (*Agrilus planipennis*)	Larva (endoparasite)	USA, Canada	Yang *et al*., 2006 [50]; Duan *et al*., 2012 [13]
Closterocerus chamaeleon	Eucalyptus gall wasp (*Ophelimus maskelli*)	Larva (ectoparasitic)	Israel, Mediterranean	Protasov *et al*., 2007 [42]
Chrysocharis flacilla	Leafminers (*Liriomyza huidobrensis*)	Larva (ectoparasitic)	East Africa	Rauf *et al*., 2000 [43]
Diglyphus isaea	Leafminers (*Liriomyza* spp.)	Larva (ectoparasitoid)	East Africa	Johnson *et al*.,[31] 1986; Rauf *et al*., 2000 [43]
Tetrastichus giffardianus	Mediterranean fruit fly (*Ceratitis capitata*)	Larva–pupa	Hawaii, Pacific Islands	Clausen *et al*., 1965 [8]; Wharton, 1989 [49]
Aprostocetus hagenowii	American cockroach (*Periplaneta Americana*)	Eggs (oothecae)	USA, Asia	Cameron, 1955 [5]; Edde & Phillips, 2006 [14]
Quadrastichus mendeli	Eucalyptus gall wasp (*Leptocybe invasa*)	Larvae (gall-forming)	Israel, Italy, Kenya, South Africa, Thailand	Mendel *et al*., 2004 [37]; Kim *et al*., 2008 [32]
Tamarixia radiata	Asian citrus psyllid (*Diaphorina citri*)	Nymphs	Brazil, USA (Florida, Texas, California), Pakistan, China	Chien & Chu, 1996 [6]; Gómez-Torres *et al*., 2006 [19]
Aprostocetus ceroplastae	Scale insects (*Ceroplastes* spp.)	Eggs & early nymphs	India, Sri Lanka, Indonesia, Pacific Islands	Hayat, 1998 [25]; Noyes, 2019 [40]

These cases highlight the adaptability, host specificity, and effectiveness of Eulophid parasitoids in reducing pest densities across diverse agro ecosystems.

Augmentative biological control

Some Eulophids are produced in large numbers and released as part of biological control programs. For example, *Diglyphus isaea* is made commercially for managing greenhouse leaf miners in vegetables and ornamental plants (Murphy & LaSalle, 1999) [39], while *Aprostocetus hagenowii* is used against cockroach pests in urban areas (Hagenbuch *et al*., 1988) [22]. Although these releases can quickly reduce pest populations, they pose challenges related to efficiently rearing, handling, and maintaining the insects in the field.

Conservation, biological control, and habitat management

Conservation biological control improves the effectiveness of Eulophid parasitoids by managing agroecosystems to support their survival and activity. Ecological engineering methods, such as providing floral resources like nectar and pollen for adult nourishment, creating refugia or alternative hosts to sustain populations during times of host scarcity, and using intercropping or polyculture systems to increase host availability, are especially effective (Delrio *et al*., 2005) [11]. These approaches collectively enhance the longevity, dispersal ability, and population stability of Eulophids, thereby reinforcing their long-term contribution to sustainable pest control.

Physiological and behavioural adaptations

Eulophids have adaptive traits that support their success in biocontrol. They locate hosts using chemical cues (kairomones, synomones), vibrations, and visual signals. Their reproductive strategies, which range from solitary to gregarious development, maximize host use. Physiological adaptations, such as thermal tolerance and diapause, help ensure survival in various climates (Charles & Allan, 2000) [5]. These traits collectively explain their ecological flexibility and effectiveness in pest suppression.

Molecular and genomic insights

Contemporary molecular methodologies have considerably advanced the research on Eulophid parasitoids. DNA barcoding employing COI and ITS2 markers has enhanced species identification and uncovered cryptic diversity (Hebert *et al*., 2003) [27]. Genomic and transcriptomic investigations have identified venom proteins and host-manipulation genes within parasitoid Hymenoptera (Falabella *et al*., 2020) [17], whereas mitochondrial genomics has underscored adaptive evolution in genes related to energy processes (Zhang *et al*., 2023) [51]. Population genetic analyses further support the surveillance of establishment and adaptation following releases (Hufbauer & Roderick, 2005) [30]. These scientific developments augment taxonomic accuracy, bolster ecological safety, and inform the selection of efficacious Eulophid agents.

Interactions with other natural enemies

Parasitoids in the Eulophid group often interact with other natural enemies in farming systems, influencing their effectiveness in pest control. When competing with other parasitoids like Braconids and Pteromalids, their efficiency can decline (Harvey *et al*., 2013; Cusumano *et al*., 2016) [24,10]. Conversely, combining Eulophids with predators or entomopathogens can produce a synergistic effect, with research indicating that nearly 80% of parasitoid-fungus combinations succeed when applied at the right time and dosage (Meyling & Eilenberg, 2017) [38]. To effectively incorporate Eulophids into sustainable Integrated Pest Management (IPM) programs, it is crucial to understand these competitive and synergistic interactions.

Non-target effects and ecological safety

Host specificity testing is a vital step before releasing Eulophid parasitoids in biological control efforts. Although most species are regarded as safe, inadequate studies on introductions can pose risks of non-target effects and unintended ecological impacts (van Lenteren *et al*., 2006) [48]. To reduce these risks, modern regulatory frameworks require strict host-range testing and thorough environmental risk assessments (Heimpel & Mills, 2017) [28], making sure only species that are environmentally safe and target-specific are approved for release.

Mass rearing and commercialization

Commercializing Eulophid parasitoids mainly relies on having suitable host species available or creating efficient artificial diets. These factors determine whether large-scale production is feasible (van Lenteren, 2012; Grenier *et al*., 1994) [46,21]. Just as important are cost-effective rearing methods that preserve parasitoid quality while reducing production costs (Smith, 1996; Leppla & Ashley, 1989) [45,35]. Additionally, raising awareness among farmers and encouraging them to adopt these methods is crucial, as it drives the actual use in the field (van Lenteren & Bueno, 2003) [47]. Right now, *Diglyphus isaea* is one of the few Eulophid species used commercially and widely in greenhouses to manage leaf miners (Liu *et al*., 2015; van Lenteren, 2012) [36,46]. However, expanding commercialization to other promising species requires further research into rearing biology, innovative artificial diets, and delivery systems to achieve large-scale, economically viable production (Cock *et al*., 2010; Heimpel & Mills, 2017) [9,28].

Climate change and future prospects

Climate change brings both challenges and opportunities for using Eulophid parasitoids in pest control. As temperatures rise, precipitation patterns change, and seasons shift, this can disrupt the timing of host and parasitoid, reduce the effectiveness of parasitism, and impact the success of establishment through range expansion or contraction (Deutsch *et al*., 2008) [12]. These mismatches may undermine the long-term stability of biological control, especially in open-field farming systems. To forecast performance in future scenarios, predictive modelling that combines climate variables with host–parasitoid dynamics will be crucial (Bale *et al*., 2002) [1]. Additionally, developing climate-resilient strains through selective breeding or pre-adaptation strategies could help maintain control effectiveness in rapidly changing environments (Hoffmann & Sgrò, 2011) [29].

Key lessons from eulophid biocontrol

Eulophid parasitoids are effective biocontrol agents because of their quick establishment, high reproduction rates, and extensive dispersal, allowing large-scale pest control without frequent releases (LaSalle, 1994; Schauff *et al*., 1997) [33,44]. Their success depends on climatic compatibility with the release area, which enhances survival and adaptability, as demonstrated in *Quadrastichus mendeli* controlling *Leptocybe invasa* in eucalyptus (Mendel *et al*., 2004; Kim *et al*., 2008) [37,32]. Combining their use with cultural practices, sanitation, selective pesticide application, and mechanical removal improves control, reduces pest resurgence, and promotes long-term sustainability (Heimpel & Mills, 2017) [28]. These lessons highlight that climate-matched introductions and integrated strategies are essential for maximizing the potential of Eulophid parasitoids in sustainable pest management.

Knowledge gaps and research needs

Despite their significance in biological control, significant knowledge gaps restrict the broader application of Eulophid parasitoids. Key life-history traits such as host range, reproduction, and environmental tolerances remain poorly understood—for example, records of Melittobia are limited to a few species (González *et al*., 2008) [20]. Taxonomic uncertainties, particularly in morphologically conservative groups like Euplectrus, highlight the need for integrated morphology–molecular approaches (Hansson, 2004) [23]. Long-term ecological studies are rare, although climate-driven host–parasitoid asynchrony can undermine their effectiveness and pose risks to non-target species (Cariveau *et al*., 2023; Furlong & Zalucki, 2010) [4,18]. Additionally, comprehensive global databases connecting species, hosts, and control results are still absent (Noyes, 2019) [40]. Filling these gaps will enhance the accuracy, safety, and sustainability of using Eulophids in pest management.

Conclusion

Parasitoids from the Eulophid family are highly diverse and effective at controlling pests, with a proven track record in biological control. Advances in molecular biology, mass-rearing, and ecological engineering are making them more dependable and safer to use. However, we still need to address unresolved taxonomy, unclear environmental relationships, and climate-related challenges to realize their full potential. Moving forward, we should combine traditional and molecular methods, expand global databases, and encourage collaboration with other natural enemies to ensure Eulophids remain a vital part of sustainable, climate-resilient pest management.

References

1. Bale JS, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, Brown VK, *et al*. Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. Glob Chang Biol. 2002;8(1):1-16.
2. Bauer LS, Liu H, Miller DL, Gould J, Cappaert D. Developing a classical biological control program for *Agrilus planipennis* (Coleoptera: Buprestidae), an invasive ash pest in North America. Mich Entomol Soc Newsl. 2008;53:38–9.
3. Cameron E. *Aprostocetus hagenowii* (Ratzeburg) (Hym., Eulophidae), a parasite of the cockroach *Periplaneta americana* L. Bull Entomol Res. 1955;46(4):835-44.
4. Cariveau DP, Williams NM, Benjamin FE, Winfree R. Climate change disrupts synchrony between plants and insect pollinators. Annu Rev Entomol. 2023;68:199–218.
5. Charles JG, Allan DJ. Development of the eulophid parasitoid *Tamarixia triozae* (Burks) in relation to its host, *Bactericera cockerelli* (Sulc). N Z J Zool. 2000;27(4):339-43.

6. Chien CC, Chu YI. Biological control of citrus psyllid *Diaphorina citri* in Taiwan. Biol Pest Control Syst IPM, 1996, 93-105.
7. Clausen CP. Introduced parasites and predators of arthropod pests and weeds: A world review. USDA Agric Handb, 1978, 480.
8. Clausen CP, Clancy DW, Chock QC. Biological control of the Mediterranean fruit fly in Hawaii. USDA Tech Bull. 1965;1322:1–102.
9. Cock MJW, van Lenteren JC, Brodeur J, Barratt BIP, Bigler F, Bolckmans K, *et al*. Do new access and benefit sharing procedures under the Convention on Biological Diversity threaten the future of biological control? BioControl. 2010;55(2):199-218.
10. Cusumano A, Peri E, Colazza S. Interspecific competition/facilitation among insect parasitoids. Curr Opin Insect Sci. 2016;14:12–16.
11. Delrio G, Lentini A, Orrù M. Role of parasitoids in integrated pest management of citrus in the Mediterranean region. IOBC/WPRS Bull. 2005;28(6):1-6.
12. Deutsch CA, Tewksbury JJ, Huey RB, Sheldon KS, Ghalambor CK, Haak DC, *et al*. Impacts of climate warming on terrestrial ectotherms across latitude. Proc Natl Acad Sci U S A. 2008;105(18):6668–72.
13. Duan JJ, Bauer LS, Abell KJ, Lelito JP. Establishment and abundance of *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in Michigan: Potential for success in classical biological control of emerald ash borer. J Econ Entomol. 2012;105(3):593–608.
14. Edde PA, Phillips TW. Potential host range of *Aprostocetus hagenowii*, an egg parasitoid of cockroaches. Biol Control. 2006;37(2):182–90.
15. El-Heneidy AH, Adly D. Eulophid parasitoids of lepidopterous pests in Egypt. Bull Entomol Soc Egypt. 1990;69:1–9.
16. Evans EW, Gage SH. A parasitoid of the cottonwood leaf beetle *Chrysomela scripta*. Great Lakes Entomol. 2006;39:1–6.
17. Falabella P, Giordano E, Rossi M, Caccia S. Parasitoid venom: A multifunctional tool for parasitism. Toxins. 2020;12:538.
18. Furlong MJ, Zalucki MP. Exploiting predators and parasitoids in IPM programs for lepidopteran vegetable pests. Crop Prot. 2010;29:447–54.
19. Gómez-Torres ML, Nava DE, Gravena S, Parra JRP. *Tamarixia radiata* as a biological control agent of *Diaphorina citri* in Brazil. Fla Entomol. 2006;89:531–3.
20. González F, Sharma A, Mathur S. Life history traits of Eulophidae parasitoids: Implications for biological control. J Appl Entomol. 2008;132(6):401–9.
21. Grenier S, Pintureau B, Heddi A. Rearing and mass production of egg parasitoids. Biol Control Egg Parasitoids, 1994, 115–32.
22. Hagenbuch BE, Koehler PG, Patterson RS, Brenner RJ. Biological control of cockroaches. Fla Entomol. 1988;71(2):240–8.
23. Hansson C. Eulophidae of Costa Rica 2. Mem Am Entomol Inst. 2004;75:1–318.
24. Harvey JA, Poelman EH, Gols R. Development of hyperparasitoids in a multi-trophic context. Ann Entomol Soc Am. 2013;106(3):349–62.
25. Hayat M. Aphelinidae of India: A taxonomic revision. Mem Entomol Int. 1998;13:1–416.
26. Haynes DL, Gage SH. Potential role of parasitoids in regulating populations of the elm leaf beetle. Environ Entomol. 1981;10(5):547–51.
27. Hebert PDN, Cywinska A, Ball SL, deWaard JR. Biological identifications through DNA barcodes. Proc R Soc Lond B Biol Sci. 2003;270:313–21.
28. Heimpel GE, Mills NJ. Biological control: Ecology and applications. Cambridge: Cambridge Univ Press, 2017.
29. Hoffmann AA, Sgrò CM. Climate change and evolutionary adaptation. Nature. 2011;470:479–85.
30. Hufbauer RA, Roderick GK. Microevolution in biological control: Mechanisms, patterns, and processes. Biol Control. 2005;35(3):227–39.
31. Johnson MW, Oatman ER, Wyman JA. Effects of parasitism by *Diglyphus isaea* on populations of *Liriomyza sativae*. J Econ Entomol. 1986;79(3):1129–33.
32. Kim IK, Mendel Z, Protasov A, Blumberg D, La Salle J. Taxonomy, biology, and efficacy of *Quadrastichus mendeli*. Biol Control. 2008;45(3):368–78.
33. LaSalle J. North American genera of Tetrastichinae. J Nat Hist. 1994;28(1):109–36.
34. LaSalle J, Gauld ID. Hymenoptera: Their biodiversity and impact. In: LaSalle J, Gauld ID, editors. Hymenoptera and biodiversity. Wallingford: CAB Int, 1993, 1–26.
35. Leppla NC, Ashley TR. Quality control in insect mass production: A review and model. Bull Entomol Soc Am. 1989;35(3):33–44.
36. Liu TX, Kang T, Xie J. Commercial mass rearing and release of *Diglyphus isaea* in greenhouses. Insects. 2015;6(3):842–50.
37. Mendel Z, Protasov A, Fisher N, La Salle J. Taxonomy and biology of *Quadrastichus mendeli*. Phytoparasitica. 2004;32(2):109–20.
38. Meyling NV, Eilenberg J. Ecology of entomopathogenic fungi. Adv Genet. 2017;94:67–103.
39. Murphy ST, LaSalle J. Balancing BC strategies for Liriomyza leaf miners in vegetables. Biocontrol News Inf. 1999;20(3):91–104.
40. Noyes JS. Universal Chalcidoidea Database. Nat Hist Mus London, 2019 [cited year]. Available from: http://www.nhm.ac.uk/chalcidoids
41. Prinsloo GL. South African Eulophidae parasitic on psyllids. J Entomol Soc South Afr. 1980;43(2):189–201.
42. Protasov A, LaSalle J, Blumberg D, Mendel Z. A new species of *Closterocerus*. Zootaxa. 2007;1496:47–57.
43. Rauf A, Shepard BM, Johnson MW. Leaf miners in Indonesia: Host crops, species composition and parasitoids. Int J Pest Manag. 2000;46(4):257–66.
44. Schauff ME, LaSalle J, Coote LD. Eulophidae of Costa Rica 1. Mem Am Entomol Inst. 1997;57:1-390.

45. Smith SM. Biological control with *Trichogramma*. Annu Rev Entomol. 1996;41:375-406.
46. van Lenteren JC. State of commercial augmentative biological control. BioControl. 2012;57(1):1–20.
47. Van Lenteren JC, Bueno VHP. Augmentative biological control in Latin America. BioControl. 2003;48(2):123–39.
48. Van Lenteren JC, Bale J, Bigler F, Hokkanen HMT, Loomans AJM. Risks of releasing exotic BC agents. Annu Rev Entomol. 2006;51:609–34.
49. Wharton RA. Classical BC of fruit-infesting Tephritidae. In: Robinson AS, Hooper G, editors. World crop pests: Fruit flies. Amsterdam: Elsevier, 1989, 303–13.
50. Yang ZQ, Strazanac JS, Marsh PM, van Achterberg K, Choi WY. First recorded parasitoid of *Agrilus planipennis* from China. Proc Entomol Soc Wash. 2006;108(3):550–8.
51. Zhang H, Li Y, Wu H. Mitochondrial genome evolution in parasitoid Hymenoptera: Insights from Eulophidae. Insects. 2023;14(2):167.