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***Research Article** (Open Access)*

A SPECIES OF THE GENUS *TAMARIXIA* (HYMENOPTERA: EULOPHIDAE) PARASITIC ON GALL FORMING TRIOZID (HOMOPTERA: PSYLLOIDEA: TRIOZIDAE) INFESTING THE LEAVES OF *TERMINALIA ARJUNA* IN UTTARAKHAND (INDIA)

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ABSTRACT
This study was principally conducted to assess the diversity of Eulophids, predominately Tetrastichine wasps and their host-parasite complex on Arjun tree, *Terminalia arjuna*. *T.arjuna* has a significant role in medicinal purpose. Various parts of *T. arjuna* have been used for curing of many diseases like asthma, bile duct disorders, scorpion stings, and poisonings. The bark of *T. arjuna* primarily used in the remedy of heart-related diseases. During the taxonomic investigation authors encountered with one species of the genus *Tamarixia* emerged from the irregular spherical leaf galls in which a species is identified and redescribed as *Tamarixia sheebae* Narendran (Hymenoptera: Eulophidae: Tetrastichinae). For the healthy production of leaves of *T. arjuna*, this parasitic wasp can be used to manage the infestation caused by this pest.

Keywords: *Eulophidae, Tamarixia, Terminalia arjuna, Tetrastichinae, Triozidae.*

INTRODUCTION
The order Hymenoptera has many families, but Eulophidae is one of the largest and very economically important family for insect pest management. The Sub-family Tetrastichinae is one of the largest subfamily in comparison to other subfamilies of Eulophidae. The genus *Tamarixia* Mercet is diverse and related to 54 known species (Noyes, 2019). Nine species of *Tamarixia* are found in India (Narendran, 2007) and many species of *Tamarixia* are used in pest management biological control (Qureshi *et al.* 2009; Rojas *et al.* 2015).
Many species of the genus *Tamarixia* are primary parasitoids of hosts in plant galls produced by various gall-forming insects. This tetrastichine wasp was parasitizing to a gall-forming Triozid (Homoptera: Psylloidea) causing leaf gall on *T. arjuna*. The members of the family Triozidae are a very serious pest as gall formers of many economically important trees.
The ecto-endoparasitoid habit of *Tamarixia* species have been reported in several sources. In this study *Tamarixia* is parasitizing a triozid of Family Triozidae. Most of the members of Triozidae are gall-forming. It is a very serious pest of many economically important plants. The following parasitoid could be used for control of insect pest.

MATERIALS AND METHODS
Terminalia arjuna infesting leaf galls were collected from Shripur-bichwa region of Khatima, US Nagar, Uttarakhand, India during August 2018 and then these leaf galls were brought to the laboratory for rearing and kept in glass containers covered with a muslin cloth. Then, the collected material was observed for the emergence of parasitoids on daily basis. After emergence, the parasitoids were collected in 75% ethanol with the help of aspirator or brush. The procedure prescribed by Noyes (1982) for preparing permanent slides was followed to observe the taxonomic character of the collected specimen. Olympus Magnus MSZ-TR (Binocular Stereo Microscope) was used to take various photographs and Olympus Trinocular Research Microscope Model- CX-31-Tr with drawing tube attachment was used for the drawing (Kumar *et al.* 2018).

Terminology and abbreviations used in this paper have been adopted from Gibson (1997) Abbreviations are: F1, funicle segment 1; F2 funicle segment 2; F3 funicle segment 3; POL, postocellar length; OOL, ocellocular length; SMV, submarginal vein; MV, marginal vein; PMV, postmarginal vein; SV, stigma vein. All measurement in millimeter (mm) was used.

RESULT AND DISCUSSION

Tamarixia sheebae Narendran

Redescription of species

Female (Plate C Fig. 1): Body length about 1.45 mm; body colour black and yellow; head black, ocelli yellow and eyes red; antennae pale yellow; Thorax black, pronotum black; legs pale yellow exept coxa; gaster dorsally brown except basal region yellow and ventrally yellow .

Head (Plate C Fig. 2, 3; Plate D Fig. 1): Wider than long in frontal aspect (0.37 : 0.32), smooth and sparsely setose, head frontal grooves present inverted V in shape; fronto vertex setae short and sparse; ocelli arranged in obtuse angled triangle; POL 0.34× as long as OOL; compound eyes bulged, large and smooth, eyes orbit round, facets of uniform shape and size; antennal toruli located slightly up from the lower of eyes margin, prominence between antennal toruli less than 2.83× the width of frons between eyes (0.06 : 0.17); malar sulcus present; malar space smooth; mandibles tridentate with 2 acute teeth; clypeus indistinctly incised.

Antennae (Plate C Fig. 4; Plate D Fig. 2): Eight segmented excluding 1anellus, antenna with long terminal spine, antennal formula 1,1,1,3,3; scape cylindrical slightly more than 4× as long as wide (0.16 : 0.04), scape apex touching to mid ocelli but not extending above the vertex; pedicel sparsely setose, more than 1.5× as long as wide (0.06 : 0.04) and slightly shorter than the length of the FS1; funicle 3 segment, FS1 to FS3 gradually increasing in length, FS1 1.4× as long as wide (0.06 : 0.04), FS2 2× as long as wide (0.06 : 0.03), FS3 2× as long as wide (0.06 : 0.03) club 3 segmented, more than 2.82× as long as wide (0.14 : 0.05) more than preceding two funicle segments combined.

Thorax(Plate C Fig. 5; Plate D Fig. 3): Pronotum covered with setae in scattered way , anterior margin not concave in the middle; mesoscutum 1.4× as wide as long (0.31 : 0.21); mesoscutum having 2 pairs of adnotaular setae, notuli incomplete and deep, median longitudinal grooves present; axilla advanced; scutellum slightly convex and sculptured, shorter than mesoscutum, less than 1.4× as wide as long (0.19 : 0.13) with longitudinal grooves and 2 pairs of setae situated outside of grooves on scutellum, grooves deep and straight; dorsellum sculptured and bulged and more than 2.66× as wide as long; propodeum with median carina and without paraspiracular carinae, propodeal spiracles rounded and large, not well separated from the anterior margin of propodeum, spiracle rim fully exposed.

Forewings (Plate C Fig. 8; Plate D Fig. 4): More than 2.3× as long as wide (0.98 : 0.42), more than 1.3× longer than hind wing length, densely setose; costal cell long and bare, SMV with 1 setae directed upwards, longer (0.23) than MV (0.21); MV bearing 8 long setae on frontal edge; PMV rudimentary; length of MV (0.21) 2.62× of SV (0.08) shorter; basal vein present; speculum narrow and closed; cubital vein straight.

Hindwings (Plate D Fig. 5): More than 8.33× as long as wide (0.75 : 0.09) with acute apex; vein length (0.36), 2.08× the length of wing.

Fore Legs (Plate C Fig. 7; Plate D Fig. 6): Coxa 2× as long as wide (0.16 : 0.08), 2.6× longer than fore trochanter; femur more than 5.8× as long as wide (0.29: 0.05), almost equal to tibia in length; fore tarsus shorter than length of tibia (0.22 : 0.23), TS1 shorter than next two tarsal segments (0.04 : 0.11), TS11.3× longer than fore tibial spur length, tarsus white.

Mid Legs(Plate D Fig. 7): Coxa more than1.2× as long as wide (0.11 : 0.09), 1.1× longer than mid trochanter; femur 4.6× as long as wide (0.28 : 0.06), less to tibia in length; mid tarsus shorter than length of tibia (0.29 : 0.36), TS1 shorter than next two tarsal segments (0.07 : 0.13), TS1 1.7× longer than mid tibial spur length, tarsus white; mid tibial spur much longer than fore tibial spur but shorter than hind tibial spur.

Hind Legs (Plate D Fig. 8): Coxa about 2× as long as wide (0.19 : 0.09), 1.1× longer than hind trochanter; femur 3.3× as long as wide (0.31 : 0.09), less than the tibia in length; hind tarsus shorter than the length of tibia (0.32 : 0.37), TS1 shorter than next two tarsal segments (0.08 : 0.18), TS11.4× longer than hind tibial spur length, tarsus white.

Gaster (Plate C Fig. 9): Six segmented, large and tilted upward at the posterior end of gaster, more than 2× as long as wide, gaster surface smooth, densely setose, first two gasteral tergites having yellow patch and other tergites brown, gasteral apical tip tilted upwardly, petiole indistinct, broder than longer; metasoma longer than mesosoma; ovipositor sheaths slightly exerted; first valvifer semicircular, (Plate D Fig. 9); anterior margin of basal part of second valvifer much curved; third valvulae 4× as long as wide (0.08 : 0.02), less than2.4× the length of second valvifer (0.20); outer plates of ovipositor shorter than second valvifers, hypopygium reaching to last turgum of gaster.

Remarks: This species belong to the genus *Tamarixia*. The species is *Tamarixia sheebae* Narendran as per Narendran (2007), but it has some intraspecific variations in characters.

	Material Examined	***Tamarixia sheebae***
Foreleg	Fore coxa black (Plate C fig. 7; Plate D fig. 6).	Pale yellow
Mandibles	Tridentate (Plate C fig. 3; Plate D fig. 1).	Bidentate
Scutellum	Shorter than Mesoscutum (Plate C fig. 5; Plate D fig. 3).	Longer than Mesoscutum
Antenna	1 Anellus (Plate C fig. 4; Plate D fig. 2).	2 Anellus

Male: Paramere apically pointed and one parameral seta; digitus gradually decreasing width from its base to apical and sharply curved outwardly; clasper single and small in size; aedeagal apodeme is touching to the posterior end of phallobase.

Some characters of the male are differing from the female.

1. Number of funicles are 4 (Plate E fig. 3).
2. Club is longer than female club (Plate E fig. 3).
3. Thorax length and width are more than female thorax (Plate E fig. 4).
4. Yellow patch smaller and brown colour more explore in comparison to female gaster (Plate E fig. 6).
5. Gaster shorter in length but width is more than female gaster (Plate E fig. 6).
6. Gaster not tilted (Plate E fig. 1)

Plate A (Fig 1-6): Leaf galls of *Terminalia arjuna*

Material Examined: 20 ♀, (1 ♀ after taking photographs dissected and mounted on a slide under coverslip). INDIA: Shripur-Bichwa region, Khatima, Uttarakhand August 2018: (from galled leaves provided by Sangeeta Rawat); *ex.* Psylloid *Trioza hirsute* (Crawford) (Hemiptera: Triozidae) forming leaf galls on *Terminalia arjuna*. Hym. Eulo. Nr TM 001 (Vishal Kumar).

Several species of the genus *Tamarixia* are parasitoids of various gall forming insects. In this study tetrastichine wasp was parasitizing to a gall forming Triozid (Homoptera: Psylloidea) causing leaf galls on *Terminalia arjuna*. The members of the family Triozidae are very serious pest as gall formers of many economically important trees. Some genera of Psylloidea- *Caillardia* Bergevin (Aphalaridae), *Bactericera* Puton (Triozidae), *Diaphorina* Löw (Liviidae), *Trioza* Förster (Triozidae) and *Heteropsylla* Crawford (Psyllidae) have been reported as hosts of many *Tamarixia* species (Yefremova *et al.* 2018).

Plate B (Fig. 1-8): Gall forming Triozid, *Trioza hirsute* (Crawford)

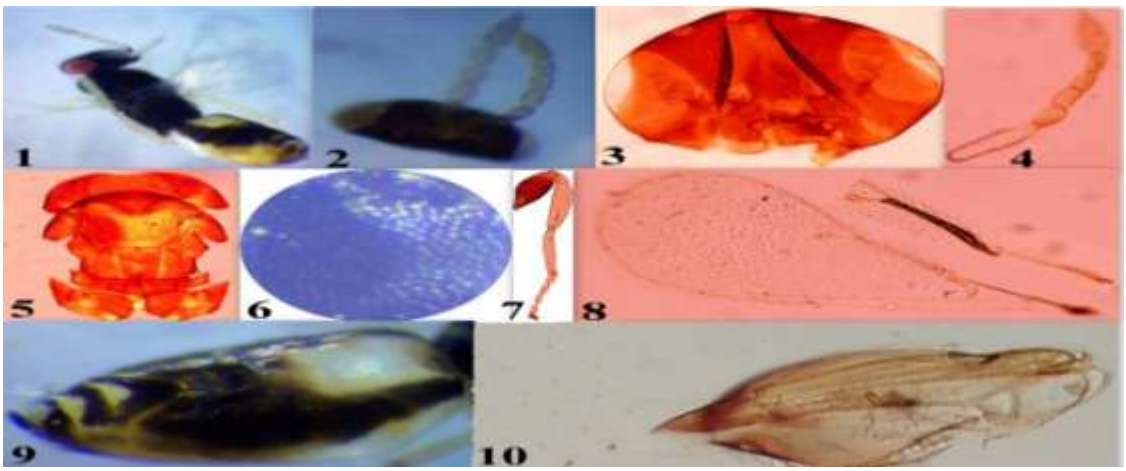

Plate C (Fig. 1-10): 1- Female Habitus, 2- Head and antenna (After bleaching), 3- Head frontal view (After dissecting), 4- Antenna, 5- Thorax dorsally, 6- Mesoscutellum sculpture, 7- Fore leg, 8- Fore wing, 9- Abdomen dorsally, 10- Female genitalia.

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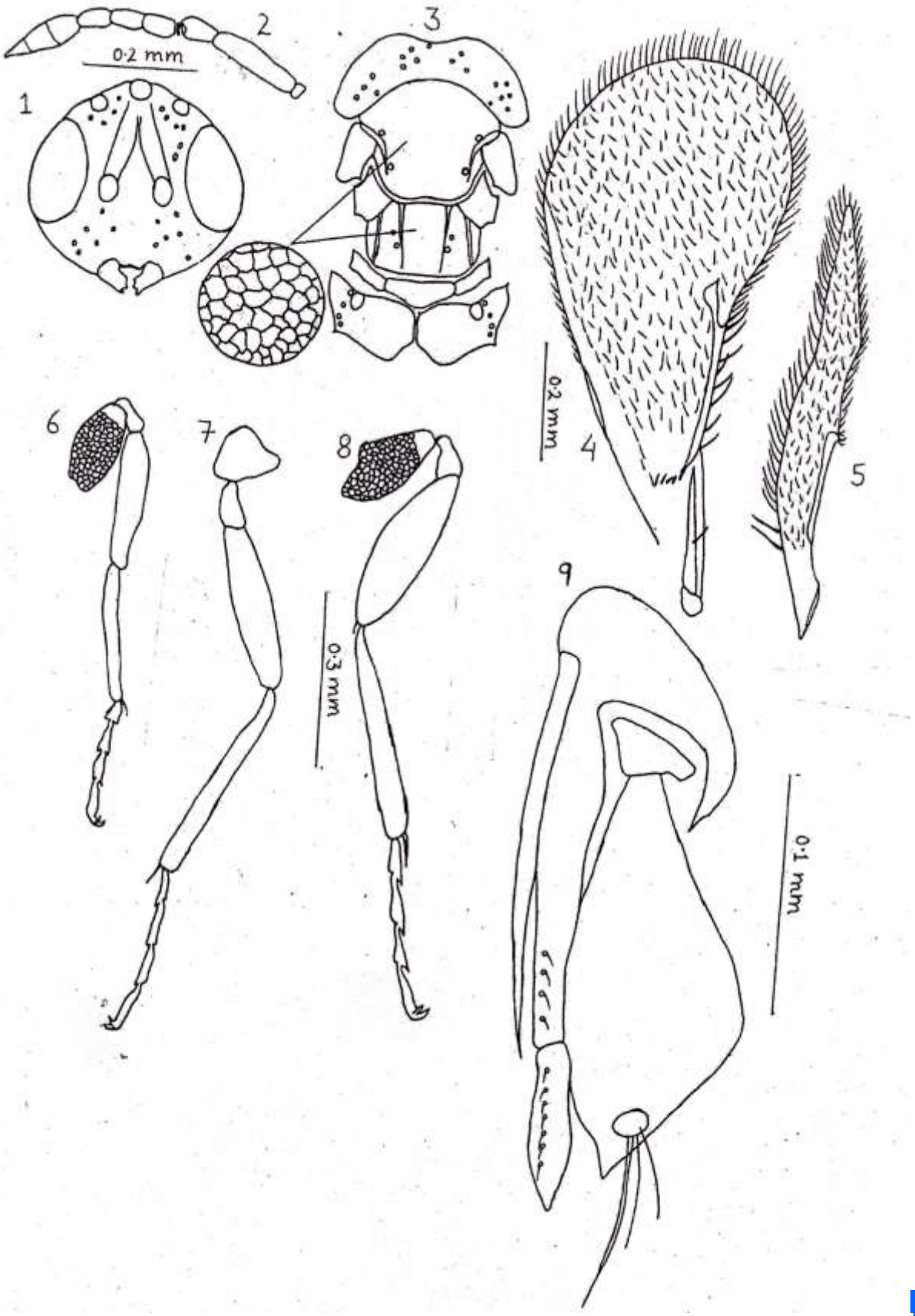

Plate D (Figs. 1-9): 1- Head , 2- Antenna, 3- Thorax , 4- Fore wing, 5- Hind wing, 6- Fore leg, 7- Mid leg, 8- Hind leg, 9- Female genitalia.

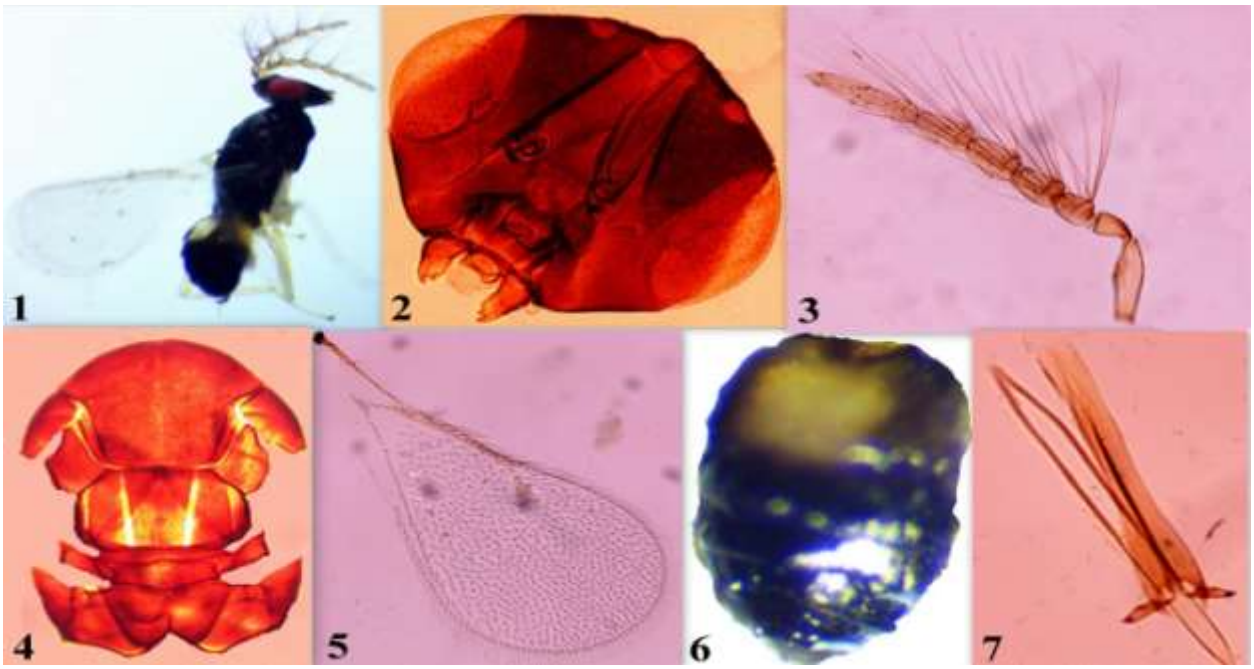

Plate E (Fig. 1-7): 1- Male Habitus, 2- Head frontal view (After dissecting)), 3- Antenna, 4- Thorax dorsally, 5- Fore wing, 6- Abdomen dorsally, 7- Male genitalia.

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