Plant Archives Vol. 24, Special Issue (VS), 2024 pp. 215-219 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.splecialissue.034

NATURAL CRYPTIC AUDIO-VISUAL APOSEMATIC DEFENCE MECHANISMS IN TROPICAL TASAR INSECT *ANTHERAEA MYLITTA* DRURY

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ABSTRACT

Antheraea mylitta Drury is a polyphagous wild sericigenous insect distributed in India, Sri Lanka, Nepal and China. They are reared in the moist deciduous forests of India exhibiting single to multiple life cycles in a year depending on the altitude. As these insects grow in wild/outdoor conditions it is natural to have predators at each stage of their life cycle. It is also quite natural these insects developed a multitude of defence mechanisms to protect themselves. The tasar insects exhibit various crypsis, visual and audio aposematism to protect themselves at each stage of their life cycle. The larvae exhibit prominent green body colour with multiple shining spots resembling the leaf surface needing trained eyes to spot the cryptic larvae apart from simple startle pose, regurgitation and thrashing the head from side to side against predation. The pupa exhibits a thick cemented cocoon as a mechanical protection against insect predators. During the adult stage, the moths exhibit broad wings with prominent eye spots resembling a larger animal exhibiting visual aposematism. Surprisingly, the tasar insects exhibit auditory aposematism from egg stage to adult stage. The developing embryo inside the eggs and larvae from third to fifth instar produce mandibular high pitch clicking sound to ward of predators and possible acoustic bats coupled with regurgitation. The adults exhibit sound absorbing fine scales on the dorsal side of their wings but thick burrowed sound reflecting ridges on the edges acting as a perfect auditory decoy echoes towards preying bats in the night.
Keywords: Mimic, camouflage, click, eyespot, bat-insect race.

Introduction

India is the second largest producer of silk in the world and is aimed to become number one. Major quantum of the silk is produced from mulberry based silkworm *Bombyx mori*. However, India also produces a host of other wild silks viz., eri (*Samia cynthia ricini*, muga (*Antheraea assama*), temperate (*A. proylei* Jolly) and tropical tasar (*A. mylitta* Drury).

A. mylitta is a tropical wild sericigenous insect known for producing tasar silk. It is mainly reared by tribal and marginal people of the tropical forests of India (Vishaka *et al*., 2020). Of the total 45 ecoraces including the recently added Gajapati (Kar, Lokesh, and Sahay 2017, https://ctrti.res.in/wp-content/uploads/2023/03/concluded-2021-22.pdf), the Daba is the ruling economically important ecorace reared in 10 states of India chiefly because of its amenability to human handling (Lokesh *et al*., 2016). The insect is reared wild in outdoors in either economical plantation or in forest patches, and the grainage or seed production is conducted indoors (Mohanraj *et al*., 2021). Apart from the commercially exploited Daba ecorace, Central Tasar Research and Training Institute (CTR&TI), Ranchi is conserving the above 45 Indian tasar ecoraces in-situ in the peripheral forest areas involving the local tribals using indigenous pagoda structures providing natural preservation and seed production (Kumar *et al*., 2020).

After consistent efforts by CTR&TI from the year of establishment 1964, two major milestones covered: 1) stabilising and consistent improvement in the production of tasar cocoons by standardisation of technology, breeding, development of package of practices and prudent extension works, and 2) surveying, cataloguing and *in-situ* conservation of ecorace gene pool. These humble wild tribal tasar silkworms are augmented with a plethora of mechanical, chemical and biological inputs to improve the feed, performance and survivability of tasar silkworm from a wide variety of pests and predators by CTR & TI (https://ctrti.res.in/technical-bulletin/). However, the insect hosts a range of crypsis and audio-visual aposematism from the egg stage to the adult stages which is widely overlooked or revealed very recently. This paper describes all the simple defence mechanisms exhibited by *A. mylitta* during rearing and seed production.

Crypsis and defence in *A. mylitta*

Crypsis is defined as the ability of an organism to conceal itself especially from a predator by having a color, pattern, and shape that allows it to blend into the surrounding environment (Endler, 1981).

As mentioned above, the tasar larvae are reared in outdoor conditions with the help of silkworm rearers. Despite the human assistance the larvae had to go through a spectrum of pests and predators from simple insects to higher animals including avian pests (Bawaskar *et al*., 2022; Reddy *et al*., 2020; Siddaiah *et al*., 2014; Chandrashekharaiah *et al*., 2022; Selvaraj *et al*., 2020). The larvae try to hide themselves from each of these predators at each stage of the life cycle. At the chawki stage or the first two instars of the life cycle, the larva tend to aggregate together under the leaf surface to suck the sap from the leaves and avoid sunlight (Fig. 1A). This mass aggregation and avoiding easy detection by hiding under the leaves gives them an undue advantage to cross the sensitive early stages of their life cycle. Regardless, the menace of reduviid bug (*Sycanus collaris*), stink bug (*Canthecona furcellata* Wolf), wasp (*Vespa orientalis*), praying mantis (*Hierodula bipapilla*), red and black ants to young age tasar larva needs human assistance in the form of mechanical nylon net, lassa-adhesive and 2% methyl-parathion dusting under the trees (Singh *et al*., 2020).

After the chawki stage, the larva enters the late age stages such as third to fifth instar. Tasar larvae exhibit four typical body colours viz., green, yellow, blue and almond according to their genetic dominance (Jolly, Narasimhanna, and Bardaiyar 1969; Kumar *et al*. 2020). Tasar larvae exhibit majorly of green larval body colour with variant number of lateral shining spots on their lateral body resembling the leaf colour needing trained eyes to spot them (Fig. 1B,C). This elegant mimicking of the leaf colour is a clear case of cryptic camouflage in tasar silkworms. These larvae when disturbed or perusing threat from predators exhibit a startling sphinx pose by ingesting the mandibular head into the body to resemble an unusual object (Fig. 1D). Also, the larva hosts a bunch of setae on their head and by wagging their head side by side ward off the disturbing/clinging pests. Not withstanding, if the larvae were disturbed hard or when tried to forcefully picked from the host plant regurgitates the ingested fluid which is normally perceived as poisonous including ants which tend to avoid regurgitated worms on choice (Brown, Boettner, and Yack 2007). The tasar silkworm produce a hardened thick silken cocoon looking like plant seeds (Fig. 1E) to protect themselves from the pest/predators and to harsh climate in the ensuing summer (Chandrashekharaiah *et al*., 2022). Thus, the wild tasar silkworm exhibit multiple visual cryptic and defence mechanisms to protect themselves out in the nature.

Audio-visual aposematism

Aposematism is defined as the use of signals *viz.,* a visual bright color, warning odor or sound of conspicuous nature by an animal to warn predators that it is toxic or distasteful (Caro and Ruxton, 2019).

Tasar silkworm exhibit a unique audio aposematism from egg stage to fifth instar stage utilizing their mandibles to produce a peculiar '*click*' sound. The click sound is clearly audible in the egg incubation room during the course of their embryo development and even when they are transferred from one place to other during seed supply. Also, from third to fifth instar stage the developing larvae produces prominent clicking sounds in the field which is quite clearly audible from distance. These clicking sounds are considered as warning signs produced after pest attack and is often followed by regurgitation which has to be studied in *A. mylitta*. Other Saturniidae such as *Actias luna* Linn and *Rhodia fugax* Butler also produce clicking sounds. The sound-based defence is well studied in A. *polyphemus* where the click frequency was measured around 8-18 kHz with 50-55 clicks per minute and its intensity range from 58.1-78.8 dB. These clicks are followed by regurgitation towards the attack and is reported to be re-ingested by the silkworm (Brown, Boettner, and Yack, 2007).

The tasar *A. mylitta* silk moth also exhibit a peculiar visual aposematism with large wings and eyespots on both the wings resembling the larger predator avian animal owl. Also, the eyespots on individual wings with curved wingtip resembles the cobra head (Fig. 2). Interestingly, it was reported that the Lepidopteran dorsal moth body and wings are covered with minute sound absorbing scales protecting the insects from the bats (Neil *et al*., 2020). Further, the wing tips of multiple Saturniids including *A. atlas*, *S. cynthia*, *A pernyi*, *A. polyphemous* contain multiple ridges reflecting the ultrasonic sound back at an angle to be detected by bats. These ridges appear far away from the body of moth at the wing tip directing the bat to the wings rather than the adult body acting as an acoustic decoy (Neil *et al*., 2021). Tasar silk moth *A. mylitta* also exhibit multiple ridges on their wingtips (Fig. 3) which would function in the same way as mentioned above. Together, *A. mylitta* exhibit an elegant audio-visual cryptic aposematism at the adult stage in the wild.

Conclusion

The tasar silkworm *A. mylitta* exhibit multiple audio-visual cryptic aposematism and defence mechanisms such as clicking sounds in developing embryo & late age larvae, camouflage green larval body colour with lateral shining spots mimicking the leaf surface, thrashing of setae containing head from side to side, and startle sphinx pose to mimic unusual objects to pests and regurgitation to warn and ward off pests. The adult moth containing large wings with eyespots mimicking larger harmful animals viz., owl and snake heads. Also, the moth contains acoustic sound absorbing scales on the body and sound reflecting ridges on the wingtip acting as acoustic reflector decoy to protect the important body and directing the bats to less important wing tip rendering protection in night.

Figures

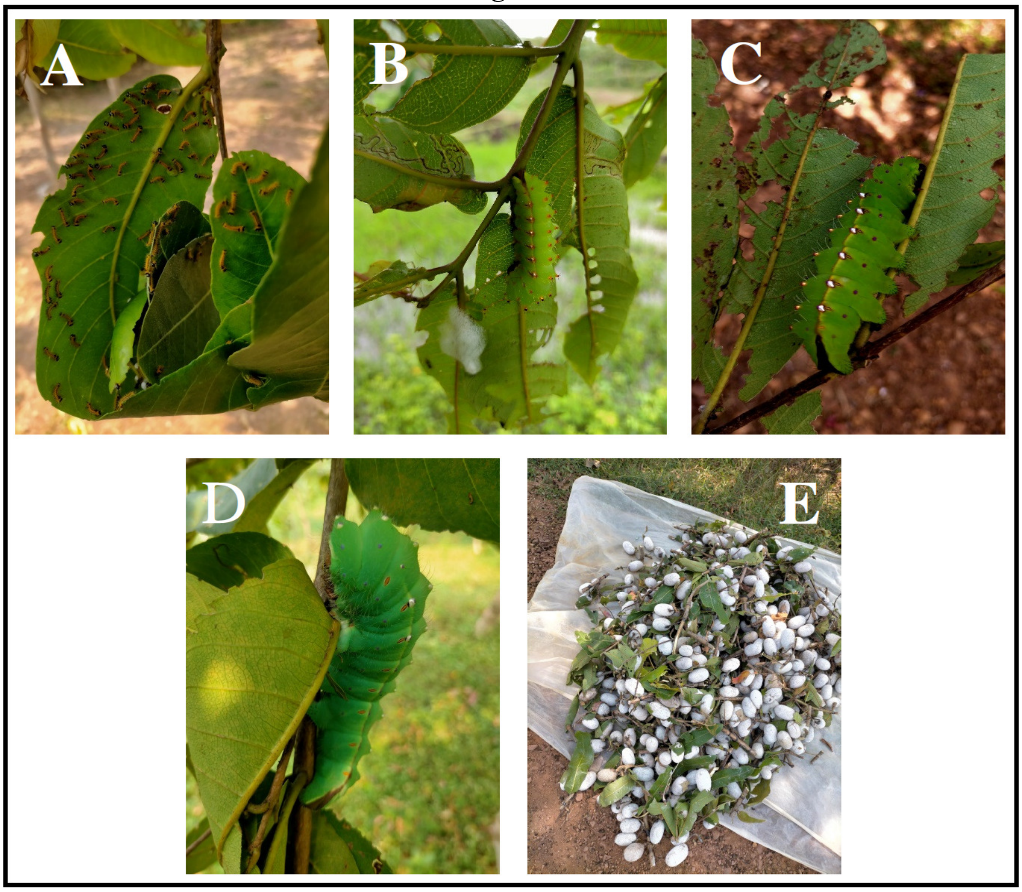

Figure 1. Crypsis in tasar larvae. A) Newly hatched tasar worms feed under the leaf surface in groups to mask against sunlight and predators, B, C) visual camouflage in tasar larvae exhibiting green body colour containing shining spots to mimic the foliage, D) larvae exhibiting sphinx pose by absorbing the head into the body to mimic unusual object on disturbance by other organisms, E) harvested cocoons showing hardened thick-walled silken shells as mechanical protection against biotic and abiotic stress.

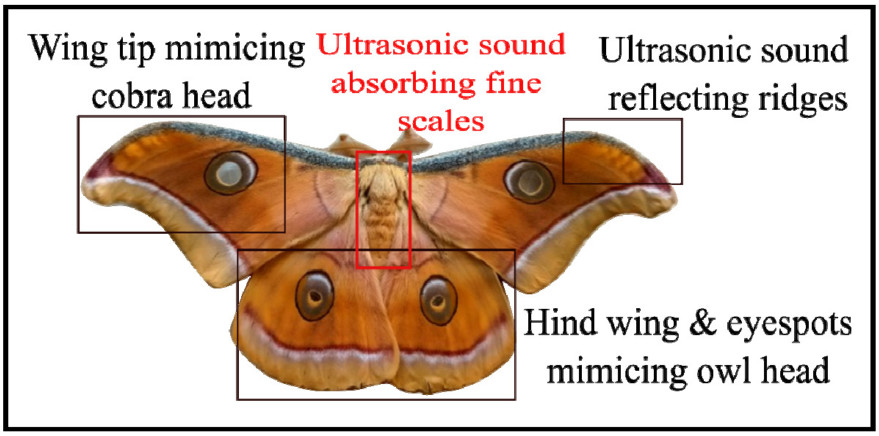

Figure 2. The adult silk moth exhibiting large wings with multiple eye spots resembling other predatory animals like owl & snake along with sound absorbing scales on the dorsal side of the moth body and sound reflecting ridges on the wingtips.

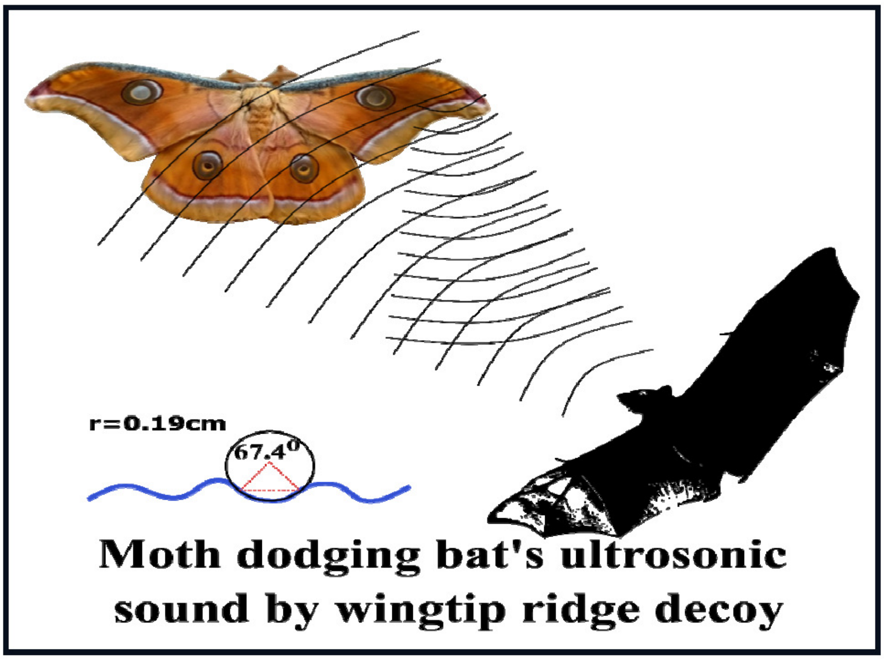

Figure 3. Imaginary depiction of tasar moth and bat's ultrasonic sound interaction depicting the absorption of sound on the moth body whereas reflection of sound from wingtip to divert bats to the wingtips to safeguard the vital body. The insert shows the angle of sound deflection from the ridges of A. polyphemus as reported by Neil *et al*. 2021.

Author contributions

SSM conceived, collected literature, noted grainage and rearing field observations, and prepared manuscript. TS and NBC gave critical suggestions during manuscript preparation. All authors read and approved the manuscript.

Declaration and competing interests

The authors declare no competing interests.

Acknowledgements

The support from Central Silk Board, Ministry of Textiles, Government of India is rightfully acknowledged. The work was not funded by any funding agency.

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