

Morphological Structure of the Body Setae as Mechanoreceptor on the Mesonotum of *Telenomus remus* Nixon (Hymenoptera, Platygasteridae)

¹*Bramantyo Wikantyo, ²Ichsan Luqmana Indra Putra

¹Research Center for Applied Zoology, National Research and Innovation Agency (BRIN), Bogor, Indonesia

²Laboratory of Ecology and Systematics, Biology Study Program, Faculty of Applied Science and Technology, Ahmad Dahlan University Yogyakarta

¹bram002@brin.go.id*; ²ichsan.luqmana@bio.uad.ac.id

*corresponding author

ARTICLE INFO

Article history

Received: June 15th 2023

Revised: June 22th 2023

Accepted: June 30th 2023

Keywords

hymenoptera

mechanosensory

natural enemy

peripheral nervous system

sensilla

ABSTRACT

Telenomus remus is parasitoid on many Lepidopteran. Morphological analysis on *T. remus* is important to understand their behavior and assess the quality of parasitoid comes from the mass rearing process. However, the information of *T. remus* body setae cuticle characteristics were limited. This study aimed to explore the body setae on the mesonotum of *T. remus* by using electron microscopy analysis and characterize their cuticle characteristics to infer the putative function of the body setae. The results showed structures that support the body setae on the mesonotum as mechanoreceptor. The structure included the long and dangling seta peg, a socket, and a gap between a socket and the base of the seta peg. The putative function related to the biology and behavior of *T. remus* were discussed.

1. Introduction

Telenomus remus Nixon, 1937, is a native species of Peninsular Malaysia and Papua New Guinea (Hernández et al., 1989). *Telenomus remus* from India was firstly introduced to Israel to control the armyworm *Spodoptera littoralis*, the sister species of *Spodoptera litura* (Gerling, 1972; Li et al., 2021). The following successful introduction of *T. remus* was in Tapa la lucha, Venezuela, in July 1987 to control *Spodoptera frugiperda* in cornfield (Hernández et al., 1989). However, not all the *T. remus* release were successful. In Florida, the two years establishment of *T. remus* in 1975–1977 had failed to control *S. frugiperda* due to climate differences with the tropical countries (Van Waddill & Whitcomb, 1982).

The female of *T. remus* starts the host recognition by drumming the eggs with her antennae and smearing the eggs with her ovipositor before laying her own eggs into the host (Gerling & Schwartz, 1974). The older the female, the time for her to lay the eggs took longer time (Schwartz & Gerling, 1974). The sex pheromones of *S. frugiperda* could also act as kairomones, by which the parasitization of *T. remus* to *S. frugiperda* eggs was increased (Nordlund et al., 1983). Thus, the orientation of *T. remus* oviposition is mediated by the function of the sensory organs located on the ovipositor and antennae as tactile and air-borne chemical sensors.

As a potential parasitoid, however, the exploration of the sensory organs of *T. remus* were very limited at this time. Some sensory receptors were recorded from the antennae of *T. dendrolimusi* and *T. reynoldsi*, such as basiconic, chaetica, trichoid, trichoid curvata, multiparous gustatory, campaniform, and stylonica sensilla (Cave & Gaylor, 1987; S. Zhang et al., 2015). The diversity of sensory receptors on the antennae of *T. dendrolimusi* was higher compared to the other organs such as mouthparts, thoracic legs, eyes, mesonotum, wings, and external genitalia (S. Zhang et al., 2015).



Although the antennae are important as multimodal sensory organs, the other body parts bear other sensory receptors that the putative function has not yet to be understood.

On insect body, the sensory receptors are often called as setae (singular: seta) when they are innervated. The putative function of the setae can also be inferred from the outer morphology and the characteristic of the cuticle. For example, mechanoreceptors on the wings or body of terrestrial and flying insect are important to receive input from the surrounding situation, such as a direct mechanical input, wind speed, wing load, or other airborne vibration (Aiello et al., 2021; Dinges et al., 2021; Fuller et al., 2014; Hengstenberg, 1988; Müller & Wehner, 2007; Wikantyoso et al., 2023; Wolf & Wehner, 2005). In this study we observed setae from the mesonotum part of *Telenomus remus* Nixon and analyze the microstructure to infer the putative function.

2. Methods

Specimen collection

Samples were collected within August 2022 – February 2023 in Bantul, Yogyakarta. Stratified random sampling method was applied for the collection. The selection of the corn plantation area was carried out by purposive sampling with the availability of the *S. frugiperda* infestation as the main criterion. The eggs of *S. frugiperda* were collected and labelled. In the laboratory, the eggs were transferred to the plastic cup and kept until the parasitoid emerge. The parasitoid was preserved in 70% alcohol for further identification and electron microscopy analysis.

Specimen preparation for electron microscopy

Collected samples were soaked into cacodylate buffer and cleaned by using ultrasonic cleaner for 5 min. Cleaned samples were subjected to prefixation, fixation, and dehydration process. Prefixation was started by adding 2.5 % glutaraldehyde in a vial with samples inside for overnight at 4°C. Samples were subjected further to fixation process by soaking them in 2% tannic acid solution for 6 hours – overnight. Fixed samples were washed with cacodylate buffer four times (5 min each time). Dehydration process was carried out by soaking the samples in the serial aqueous alcohol solution (70%, 85%, 98%, and absolute). Samples were dried by using tert-butanol and frozen in the refrigerator for overnight. The freezed samples were put into the vacuum drier and kept in the desiccator. Dried samples were attached on the sample's stubs with carbon adhesive tape. Finally, samples were coated with sputter gold target and subjected into electron microscopy analysis.

3. Results and Discussion

Setae as mechanoreceptor

The observation on *T. remus* showed that the setae on the mesonotum were not only usual hair. The structure of the hair showed several biological structures that has potential to be functional as a sensory receptor. The all setae on the mesonotum had long peg ended with tapered tip. The base of the peg were smooth and longitudinal grooves prolonged to the tip of the peg. Setae with respective characteristics were also observed in other insects' body, such as antennae, mouthpart, and legs. It is usually called as chaetica or trichoid sensilla (Yanagawa et al., 2009; S. Zhang et al., 2015; Zhang et al., 2016). those setae function might be related to the mechanoreceptor or chemo-tactile receptor (Wikantyoso et al., 2022; Y.-R. Zhang et al., 2015). However, the seta peg was surrounded by a prominent structure called as socket (**Figure 1**). It may confirm one putative function of the setae on the mesonotum of *T. remus* were related to the mechanoreceptive function. Socket on the base of the peg give the setae peg flexible movement when it receives a certain amount of vibration or distortion on surrounding cuticle (McIver, 1975; Thurm, 1965). The distortion of the cuticle will be received by the nerve system attached to the base of the peg under the socket. Eventually, the distortion is converted as a signal (Iwasaki et al., 1999) (**Figure 2**). A future study including the analysis of internal anatomy of the setae by transmission electron microscopy technique to understand further about the outer dendritic nervous system characteristics of the mesonotum setae.

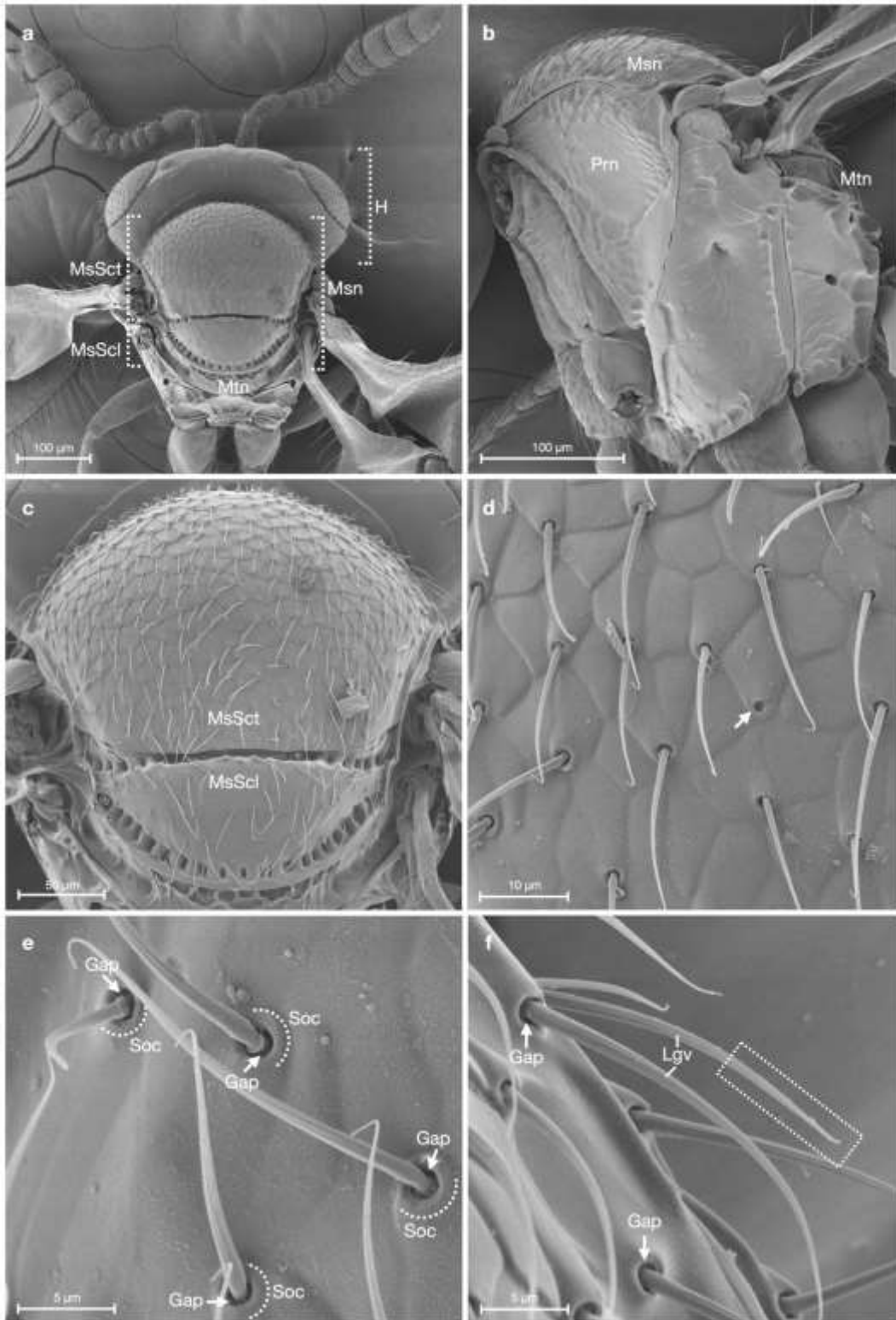


Figure 1. Setae as mechanoreceptor on the mesonotum of *T. remus*. **a:** dorsal view of mesonotum (Msn) located on the posterior side of the head (H), **b:** lateral view of the thorax showed pronotum (Prn), mesonotum, and metanotum (Mtn), **c:** closer look of mesonotum with the setae scattered on mesoscutum (MsSct) and mesoscutellum (MsScl) parts, **d:** setae socket located on the posterior side of each cuticle scale on mesoscutum (arrow), **e:** each setae has a clear prominent structure as a socket (Soc). There was a gap between the socket and the base of the setae peg that enable the setae flexibly move, **f:** the characteristics of the setae peg's cuticle showed longitudinal grooves (Lgv) appeared from the base to the tapered tip (dotted square) of the peg.

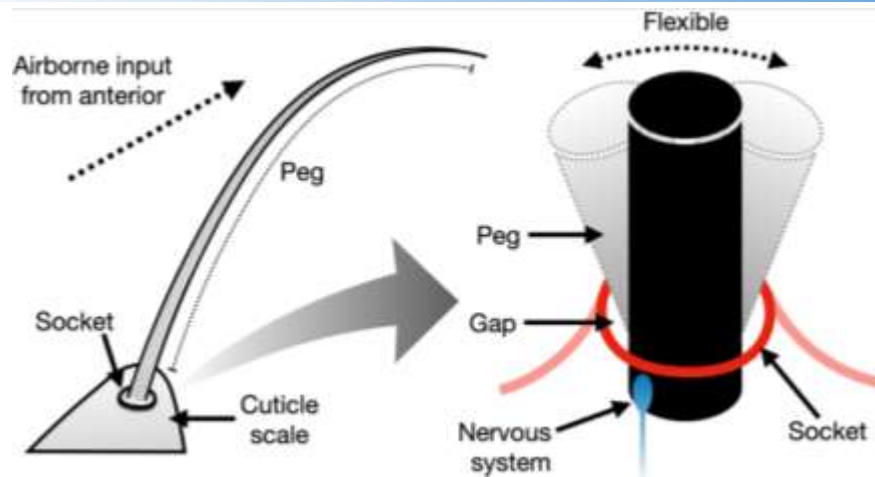


Figure 2. Schematic drawings of a seta as mechanoreceptor. The mechanoreception is mediated by long tapered peg, socket, gap, and a tubular body as the nervous system. When input comes, the gap provide flexibility to the peg to move to a certain direction. The movement of the peg may create cuticle distortion on the whole level of the peg and socket. The distortion serves as an input and will be converted to a chemical signaling by the tubular body as the peripheral nervous system.

Biological and behavioral aspects

The study of *T. remus* morphology is important to assess the deformity in the mass rearing process for the application of parasitoid as natural control agent, especially morphology related to wing size reduction related to the parasitoid flying ability (Pomari-Fernandes et al., 2016). However, the study related to the *T. remus* body setae that act as sensory organs important to support the orientation ability are limited. This study observed the existence of setae as mechanoreceptors on the mesonotum of *T. remus* that might be related to the ability to understand the air particle movement to control their flight. On the locust head, the setae on the head have the ability to respond the heavy air current (Camhi, 1969a). The wind stimulation to the locust facial setae also influences their behavior to open their wings as they are ready to fly (Camhi, 1969b). The position and direction of the dangling setae pegs might also show their importance to detect the air current from the anterior and control flying speed (Figure 2), as the deflection of the seta toward their dangling direction elicit massive action potential until the stimulus ends. But the deflection against their dangling direction did not significantly produce action potential (Corfas & Dudai, 1990). The setae might be important for the parasitoid mechanical sensitivity to a direct touch from the natural predator or surrounding obstacle such as leaves and twigs. Since the Spodoptera mostly lays the eggs under the leaves (EPPO, 2015), the long flexibly dangled setae pegs and their dense distribution may also help the orientation of the upside-down maneuver from *T. remus* during the oviposition.

4. Conclusion

The setae on the mesonotum of *T. remus* had the characteristics of mechanoreceptor. The characteristics of long peg, socket, and the gap between the base of the peg and the socket demonstrated the important structure to sense tactile or airborne mechanical stimuli.

5. Acknowledgements

The authors would like to express the gratitude to National Research and Innovation Agency (BRIN) for facilitating the electron microscopy observation and to Universitas Ahmad Dahlan for the aid with the specimen collection.

REFERENCES

- Aiello, B. R., Stanchak, K. E., Weber, A. I., Deora, T., Sponberg, S., & Brunton, B. W. (2021). Spatial Distribution of Campaniform Sensilla Mechanosensors on Wings: Form, Function, and Phylogeny. *Curr Opin Insect Sci*, 48, 8-17. doi:10.1016/j.cois.2021.06.002
- Camhi, J. M. (1969a). Locust Wind Receptors: I. Transducer Mechanics and Sensory Response*†. *Journal of Experimental Biology*, 50(2), 335-348. doi:10.1242/jeb.50.2.335
- Camhi, J. M. (1969b). Locust Wind Receptors: III. Contribution to Flight Initiation and Lift Control*. *Journal of Experimental Biology*, 50(2), 363-373. doi:10.1242/jeb.50.2.363
- Cave, R. D., & Gaylor, M. J. (1987). Antennal Sensilla of Male and Female *Telenomus reynoldsi* Gordh and Coker (Hymenoptera : Scelionidae). *International Journal of Insect Morphology and Embryology*, 16(1), 27-39. doi:https://doi.org/10.1016/0020-7322(87)90054-7
- Corfas, G., & Dudai, Y. (1990). Adaptation and Fatigue of a Mechanosensory Neuron in Wild-type *Drosophila* and in Memory Mutants. *The Journal of Neuroscience*, 10(2), 491-499. doi:10.1523/jneurosci.10-02-00491.1990
- Dinges, G. F., Chockley, A. S., Bockemuhl, T., Ito, K., Blanke, A., & Buschges, A. (2021). Location and Arrangement of Campaniform Sensilla in *Drosophila melanogaster*. *J Comp Neurol*, 529(4), 905-925. doi:10.1002/cne.24987
- EPPO, E. a. M. P. P. O. (2015). PM 7/124 (1) *Spodoptera littoralis*, *Spodoptera litura*, *Spodoptera frugiperda*, *Spodoptera eridania*. In M. Ward (Ed.), *EPPO Bulletin* (Vol. 45, pp. 410-444). doi:https://doi.org/10.1111/epp.12258
- Fuller, S. B., Straw, A. D., Peek, M. Y., Murray, R. M., & Dickinson, M. H. (2014). Flying *Drosophila* Stabilize Their Vision-based Velocity Controller by Sensing Wind with Their Antennae. *Proc Natl Acad Sci USA*, 111(13), E1182-E1191. doi:https://doi.org/10.1073/pnas.1323529111
- Gerling, D. (1972). The Developmental Biology of *Telenomus remus* Nixon (Hym., Scelionidae). *Bulletin of Entomological Research*, 61(3), 385-388. doi:10.1017/S0007485300047283
- Gerling, D., & Schwartz, A. (1974). Host Selection by *Telenomus remus*, A Parasite of *Spodoptera littoralis* Eggs. *Entomologia Experimentalis et Applicata*, 17(3), 391-396. doi:https://doi.org/10.1111/j.1570-7458.1974.tb00357.x
- Hengstenberg, R. (1988). Mechanosensory Control of Compensatory Head Roll During Flight in the Blowfly *Calliphora erythrocephala* Meig. *J Comp Physiol A*, 163(2), 151-165. doi:https://doi.org/10.1007/BF00612425
- Hernández, D., Ferrer, F., & Linares, B. (1989). Introduccion de *Telenomas remus* Nixon (Hym.: Scelionidae) Para Controlar *Spodoptera frugiperda* (Lep.: Noctuidae) en Yaritagua Venezuela. 39, 45-61.
- Iwasaki, M., Itoh, T., & Tominaga, Y. (1999). Mechano- and Phonoreceptors. In E. Eguchi & Y. Tominaga (Eds.), *Atlas of arthropod sensory receptors: dynamic morphology in relation to runction* (1 ed., pp. 177 - 190). Tokyo: Springer Japan.
- Li, Z., Wang, W., & Zhang, L. (2021). Complete Mitochondrial Genome of *Spodoptera littoralis* (Lepidoptera: Noctuidae) from Egypt. *Mitochondrial DNA Part B*, 6(2), 432-434. doi:10.1080/23802359.2020.1870894
- McIver, S. B. (1975). Structure of Cuticular Mechanoreceptors of Arthropods. *Annu Rev Entomol*, 20(1), 381-397. doi:10.1146/annurev.en.20.010175.002121
- Müller, M., & Wehner, R. (2007). Wind and Sky as Compass Cues in Desert Ant Navigation. *Naturwissenschaften*, 94(7), 589-594. doi:https://doi.org/10.1007/s00114-007-0232-4
- Nordlund, D. A., Lewis, W. J., & Gueldner, R. C. (1983). Kairomones and Their Use for Management of Entomophagous Insects. *Journal of chemical ecology*, 9(6), 695-701. doi:10.1007/BF00988776
- Pomari-Fernandes, A., de Freitas Bueno, A., & De Bortoli, S. A. (2016). Size and Flight Ability of *Telenomus remus* Parasitoids Reared on Eggs of the Factitious Host *Corcyra cephalonica*. *Revista Brasileira de Entomologia*, 60(2), 177-181. doi:https://doi.org/10.1016/j.rbe.2016.02.004
- Schwartz, A., & Gerling, D. (1974). Adult Biology of *Telenomus remus* [Hymenoptera: Scelionidae] Under Laboratory Conditions. *Entomophaga*, 19(4), 483-492. doi:10.1007/BF02372784
- Thurm, U. (1965). An Insect Mechanoreceptor. I. Fine Structure and Adequate Stimulus. *Cold Spring Harb Symp Quant Biol*, 30, 75-82. doi:https://doi.org/10.1101/sqb.1965.030.01.011
- Van Waddill, H., & Whitcomb, W. H. (1982). Release of *Telenomus remus* [Hym. Scelionidae] Against *Spodoptera frugiperda* [Lep.: Noctuidae] in Florida, U.S.A. *Entomophaga*, 27(2), 159-162. doi:10.1007/BF02375224
- Wikantyoso, B., Imai, T., Himmi, S. K., Yusuf, S., Hata, T., & Yoshimura, T. (2022). Ultrastructure and Distribution of Sensory Receptors on the Nonolfactory Organs of the Soldier Caste in Subterranean Termite (*Coptotermes* spp.). *Arthropod Struct Dev*, 70, 101201. doi:https://doi.org/10.1016/j.asd.2022.101201

- Wikantyoso, B., Ohmura, W., Imai, T., Fujii, Y., Himmi, S. K., & Yusuf, S. (2023). Sensitivity and Orientation to Sustained Airflow by *Coptotermes formosanus* Soldier Termites (Isoptera, Rhinotermitidae). *Journal of Insect Behavior*. doi:10.1007/s10905-023-09834-7
- Wolf, H., & Wehner, R. d. (2005). Desert Ants Compensate for Navigation Uncertainty. *J Exp Biol*, 208(22), 4223-4230. doi:https://doi.org/10.1242/jeb.01905
- Yanagawa, A., Shimizu, S., Noma, K., Nishikawa, M., Kazumasa, O., & Yokohari, F. (2009). Classification and Distribution of Antennal Sensilla of the Termite *Coptotermes formosanus* (Isoptera: Rhinotermitidae). *Sociobiology*, 54, 327-349.
- Zhang, S., Zhang, Z., Kong, X., Wang, H., Luo, J., & Yang, Z. (2015). Sensilla on Different Organs of Female and Male *Telenomus dendrolimusi* Chu (Hymenoptera: Scelionidae). *Microsc Res Tech*, 78(11), 1010-1018. doi:https://doi.org/10.1002/jemt.22566
- Zhang, Y.-R., Ren, L., Zhang, L., & Luo, Y. (2015). Ultrastructure of Antennal and Posterior Abdominal Sensilla in *Chlorophorus caragana* Females. *Micron*, 75, 45-57. doi:https://doi.org/10.1016/j.micron.2015.04.014
- Zhang, Z., Li, X., Chen, L., Wang, L., & Lei, C. (2016). Morphology, Distribution and Abundance of Antennal Sensilla of The Oyster Mushroom Fly, *Coboldia fuscipes* (Meigen) (Diptera: Scatopsidae). *Revista Brasileira de Entomologia*, 60, 8-14. Retrieved from http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0085-56262016000100008&nrm=iso