International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received : 02/06/2014 | Accepted on : 17/06/2014 | Published : 21/06/2014

Morphological Characteristics of Different Casts in Odontotermes Formosanus Shiraki

Ehsan Soleymaninejadian
Nanjing Forestry University Southern Modern Forestry Collaborative Innovation Center, College of Forest Resources and Environment, Nanjing Forestry University, Nanjing 210037, China

Bao-Zhong Ji
Nanjing Forestry University Southern Modern Forestry Collaborative Innovation Center, College of Forest Resources and Environment, Nanjing Forestry University, Nanjing 210037, China
E-mail: jbz9885@njfu.edu.cn

Shu-Wen Liu
The Administration Bureau of Dr. Sun Yat-sen, Mausoleum, Nanjing 210014, China

Jin-Jin Yang
Nanjing Forestry University Southern Modern Forestry Collaborative Innovation Center, College of Forest Resources and Environment, Nanjing Forestry University, Nanjing 210037, China

Xin-Wei Zhang
Nanjing Forestry University Southern Modern Forestry Collaborative Innovation Center, College of Forest Resources and Environment, Nanjing Forestry University, Nanjing 210037, China

Hong-Jiang Wang
Nanjing Forestry University Southern Modern Forestry Collaborative Innovation Center, College of Forest Resources and Environment, Nanjing Forestry University, Nanjing 210037, China

Fang Ding
Nanjing Forestry University Southern Modern Forestry Collaborative Innovation Center, College of Forest Resources and Environment, Nanjing Forestry University, Nanjing 210037, China

***Abstract* – Odontotermes Formosanus Shiraki is one of the most destructive pests for forest, agriculture crops and even dams and boats in south parts of china. The species is endemic to south, west, and south east of China, and other countries such as Taiwan, Myanmar, and Taiwan. So, the name Formosanus has given to these kinds of termites traced back to Formosa in Taiwan that first found and classified. Because the eggs need a temperature above 20 to be hatched, they only live in tropical and sub-tropical regions. They usually make subterranean cavities in a depth of 1-3 meter. In addition to queen and king, there are different kind casts in the nest, alated or reproductives, workers, soldiers, and larvae. As the termites are eusocial insects, each cast has its own duty and morphology. In this paper we described the morphology of different casts. As eggs are the base of any nests and sign of healthy nest we start from them then larvae, workers, soldiers, alated and queen and king. In addition, based on morphology differences male and female alated can be recognized. At the end we tried to explain about morphological differences between queen and king and their sizes.[1]**

***Keywords* – Isoptera, Termites, Odontotermes Formosanus Shiraki, Morphology.**

I. INTRODUCTION

The morphological research is a foundation of classification, biology, and other researches. It has received extensive attention. One of the most fundamental works in the case of morphological characteristic of *O. formosanus* Shiraki has been done by Zhu-Ge et al. at 1978 [1]. They also classified workers and soldiers into two groups based on their duty in the nest. The criteria for this classification were the head and body length and head width. Furthermore, they have classified larvae into four instars. Each instar had its own morphological characteristics; head and body length, head width, and numbers of antenna segments were the main principles for instar classification. Wang (1985) [2] described the morphological characteristics of *O. formosanus* Shiraki and *Macrotermes barneyi* Light and provided a basis for the identification and classification of them. Zhuo et al. (2004) [3]compared morphological characteristics among five common species in Hunan providence, *Reticulitermes chinensis* Synder, *O. formosanus* Shiraki, *M. barneyi* Light, *Reticulitermes flaviceps* Oshima, and *Coptotermes formosanus* Shiraki. Head length, distance between compound eyes, pronotum length, forewing length, hind wing length as the main parts had been discussed by him in all the castes. He had found that there are significant relationship among head length, distance between compound eyes, and pronotum. In addition, he mentioned that there is a significant relation between forewings and distance between compound eyes. In another paper published by Xu et al. at 2007 morphological characteristics of *O. formosanus* Shiraki such as head, body length and width have been dealt in details [4].

In contrast to above papers, some of the papers have been published specifically about one kind of castes. As alated have a different features with compound eyes and wings have been the main targets for researchers to be studied. For example Liu et al. 1985 [5] made a great research on alated reproductives. They have classified alated larvae into different classes. Wing length and body length were the scale for their research. In another study done by Zhang et al. 1993 wing microsculpturing of *O. formosanus* Shiraki and *M. barneyi* has been studied using scanning electron microscope [6]. They have revealed that wing structure has pivotal role in taxonomy and phylogenic analysis of termites. In addition to wing, morphology of compound eyes and its structure have been studied in detail by Hu et al. (2009) [7]. Eye shape, ommatidia and eye pigmentation in male and female alated have been discussed by them.

[1]This work was supported by the Specialized Research Fund for the Doctoral Program of Higher Education (grant 20123204110001) in China, the Natural Science Foundation of Jiangsu Province, China (grant BK2012816), the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), and the Funding Project of Nanjing Municipal Construction Bureau & the Management Office of Dr. Sun Yat-Sen's Mausoleum (grant 200409).

International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473

As *O. formosanus* Shiraki is one of the termite species that is one of the most hazardous species for crops and forest and even dams in China [8]-[9], characterization and identification of them can be very helpful for pest managements. First step in managing the *O. formosanus* Shiraki is morphological characterization of them. Moreover, less number of references, especially about morphology of them, in English makes it difficult for scientists to do a phylogenic analysis in this case. Above reasons solicited a good research on morphological characterization of *O. formosanus* Shiraki.

II. Materials and Methods

Nanjing Forestry University (NFU), located in the east of Nanjing, at the foot of Zijin Mountain and east of Xuanwu Lake (32° 4′ 50.66″ N, 118° 48′ 41.06″ E). All the samples were caught at the foot of Zijin Mountain. Zijin or Purple or Bell Mountain also known as mount Jiang is 447.1 m high with lowest point of 30 m. Hot damp summers and cold damp winters with short spring and fall are the main characteristic seasons in Nanjing. Annual mean temperature and rainfall are 15.2° C, and 1062 mm respectively. Zijin Mountain is covered with evergreens, oaks, bamboos and so on. In fact, 621 plant species from 383 genera and 118 different families, including 78 cultivated species are classified on the mountain.

Samples taken to the lab, collected into a plastic container (11 cm in diameter, 4 cm high) with a moist filter paper in it, and mud particles removed from them, then transferred into glass vials containing FAA (37% formalin: acetic acid: ethanol=6:1:16). All the samples kept into FAA over night. Then replace the FAA with 70% alcohol.

To see the morphology of the termites, JSZ6S (20030568) microscope (manufactured by Nanjing Jiangnan Novel Optics Co.,Ltd) with a camera (JIFEI) (manufactured by Nanjing JIFEI Technology Co.,Ltd) assembled on it has been used. The microscope was connected with computer that captured photos could be seen in a monitor. JIFEI software helped us to adjust and take the photos in the computer.

III. Results

A. Eggs

Eggs are shining, smooth cream colored with a bean shape structure. In the edges brownish color is dominant. Egg length can be seen in a range of 0.7 to 0.8 mm and the width can vary from 0.3 to 0.4.mm. The eggs shell is hard, a little sclerotized, to protect from sudden strike or transferring. Eggs contain a watery material (vitellin, yolk protein) with no color. Eggs are laid in cluster in a nest that made by both male, female, and workers (Fig.1)

B. Larvae

Hatching the eggs give very tiny miniatures that are called the newly hatched or 1st instar larva. Larvae don't have pigments in their cuticles and very sensitive and not sclerotized. During this period of time they only live in the nest and near the fungal garden to protect against predation and desiccation (Fig. 2). The antennae beads vary between11-15. Thorax is very small and undeveloped in first instars but in later ones, it can be recognized with abdomen. They usually feed by workers.

Fig.1. Shining, Smooth cream colored eggs of *O. formosanus* Shiraki

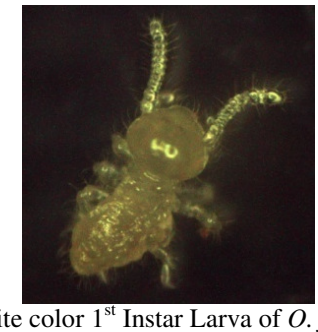


Fig.2. White color 1st Instar Larva of *O. formosanus* Shiraki

C. Workers

Head is a yellow-brownish that can be seen in the anterior part of the body. The head itself is a strong capsule like structure, as what we can see in chewing insects, that length usually is bigger than width and it is bent downward. Workers are blind, but at the eye's position the brown pigments are increased. Antennas are at both sides of the head. In the case of workers, because they have not eyes, feelers are very important in sensing the environment. They are moniliform shape structures and covered with sensillae. First segment of antenna is called scape and second segment is known as pedicle. These two parts are usually column shape and scape is bigger than pedicel and is rooted in a circle structure that is called antennal socket. Antennal socket is a little penetrated in the head structure and it is look like a foundation for antenna. After pedicle the moniliform shape flagellum can be seen. In the worker segment number of flagellum is 15, plus scape and pedicle, are 17.

Mouthparts are a little brownish or dark brown and extended toward down. Mouthparts consist of labrum, mandibles, maxillae, hypopharynx, and labium.

Labrum playing the role of upper lip in the mouth, it covers the mouth. It is very narrow in the worker and sometimes borders from clypeus cannot be distinguished.

Mandibles are also a pair of sclerotized hard structures, with dark brown colors that sometimes looking black. The teeth or endites forms are not different between two mandibles. Distance between first and second tooth are

International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473

very short and it seems these two have a crucial role in cutting the fibers (Fig. 3).

Maxillary parts are a pair of appendages in lateral parts of the head and each of them consists of five segments. As similar as antenna, maxillary parts also covered with sensilla.

Hypopharynx is tong like organ and it has two parts. To see the hypopharynx head must be dissected from the body and turn it upside down.

Labium also is a pair of appendages in lateral part of the mouth. There are two parts in the labium. In contrast with maxillary parts, sometimes first labium segment is bigger than the second one.

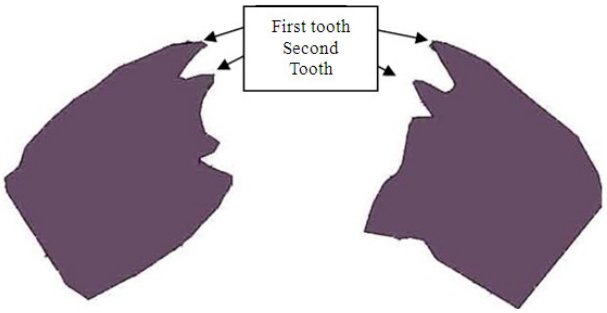


Fig.3. Incisor lobes in *O. formosanus* Shiraki worker's Mandibles

Clypeus is trapezoid structure that stands out a little in compare to other parts of the head structure. The brownish eye-like pigments are at the both end of small bases of trapezoid.

Rest of the head is occupied by frons. Seeing the head from backside, some structures such as vertex, occiput, and postgena can be seen easily.

Thorax

As what is seen in other insects, it is middle part of the body. What is seen under the microscope is different than what is seen from distance. There are some special decorations in each segment of thorax. Pronotum can be seen in the dorsal part of the thorax. It is a shield like structure of prothorax. Prothorax is larger than mesothorax and cup shaped with the edges stick out. On the other hand, mesothorax is smaller and without sharp edges. Metathorax is an extended form of mesothorax. All of the thorax segments have overlap on each other. This kind of overlapping structure make the thorax a strong shield against strikes. Main function of thorax is locomotion; each segment bears a pair of legs. It looks the pair of legs attached to mesothorax are not as strong and flexible as forelegs and hind legs (Fig. 4).

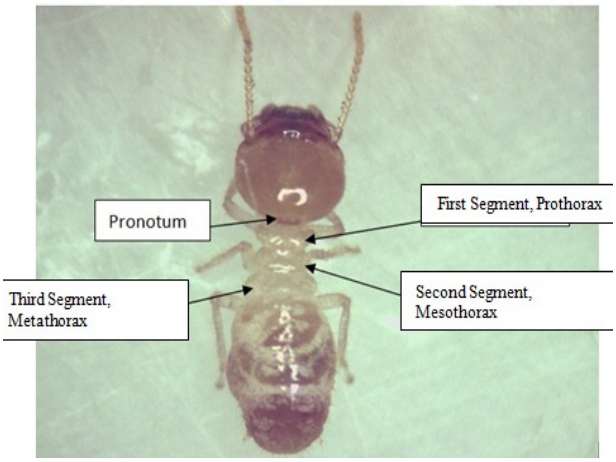


Fig.4. Worker's Thorax in *O. formosanus* Shiraki

Legs

Feature of legs in workers are something between grasping and walking type of legs. It consists of coxa, trochanter, femur, tibia, tarsus, and pretarsus (claw). In contrast to other part of leg, tarsus is made of two different segments or tarsomeres. Claws are at the end of tarsus (Fig.5a).

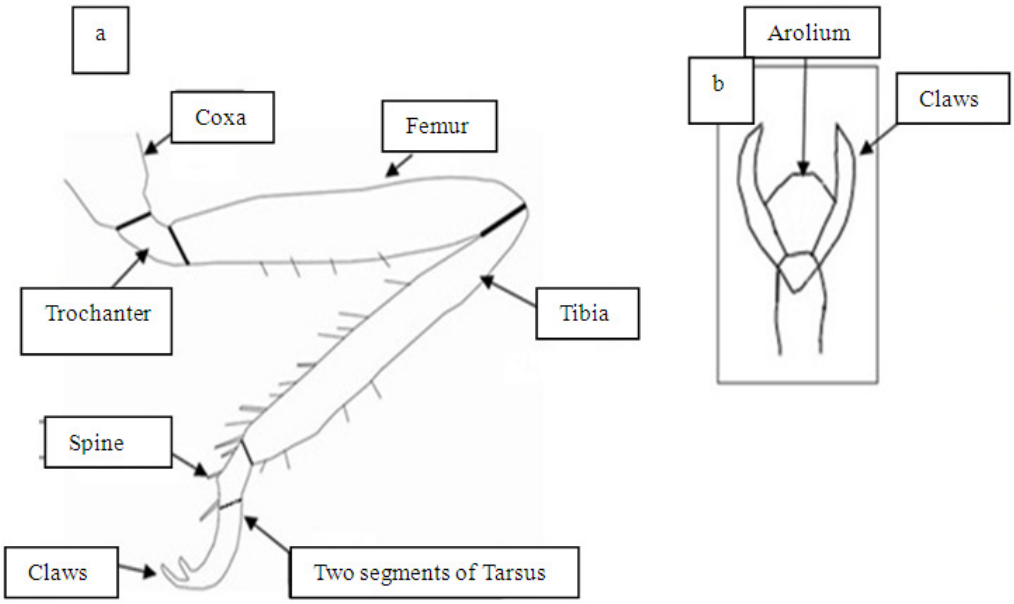


Fig.5. Different segments of leg (a), Arolium Pad in the claws (b)

Coxa is the first part of leg and it joints to thorax via trochantin. It does not have a lengthy structure; the width is bigger than any parts of the worker's leg yet. Trochanter is a small part between coxa and femur. It seems trochanter has a crucial role in passing the movement from coxa to femur. Femur is a long strong structure. As moving from coxa toward tarsus the number of articulated spines will increase on the leg's parts. Then tibia that covered with articulated spines especially the places near the tarsus. As I have mentioned before tarsus is made of two segments. The first segment is more spined and the second segment has claws at the end. Claws are hooked shape with a gap between them. This gap is a little bright in cap and darker in root. This bright part is arolium and the dark one is aroliar pad (Fig. 5b).

Abdomen

Abdomen is the posterior part of the body and has a little hump shape in the worker. It can be seen yellowish with no black spots, yellow with a little black at the anus part, half black-half yellow, and one part yellow and three parts black.

Looking from lateral perspective gives the whole view of it, sternites in the ventral, tergites in the dorsal part and bright lateral membrane in both sides of abdomen. Fat tissues can be seen all around the abdomen. Whitish of fats give a unique color to it under the microscope. However it is the softest part in the workers body, but it is very flexible and can be stretched. In addition to special role of fat in the termite metabolism, it may help to protect the digestive system from sudden strikes. There are ten sternites and tergites in the abdomen. In usual first sternite is very small and cannot be seen clearly, but all the tergites are visible under the microscope. Fourth and fifth sternites are very important because the trail pheromone will be released by some glands between these two sternites. Anus is in tenth segment and ninth sternite is a little protruded near anus. There are some appendages or cerci in the last sternites, two big in lateral and two (in total four) small in ventral part.

D. Soldiers

Strong, long flat (in compare to workers), oval shape head is first sign of a soldier (1.28-1.88mm in length and 1.15-1.43 in width). Although, basic structure of soldiers head and workers head is similar, but there are some outstanding differences. The most important differences are in the mouthparts is the mandibles. Soldiers' mandibles are very long, sometimes bigger than 0.7 mm, and sickle shape. There is a pair of them in the most anterior part of the body. *O. formosanus* Shiraki soldier has its own special type of mandibles; left mandible has a small appendage that makes it very unique. Another difference between soldiers and workers is the tong shape labrum; because soldiers' mandibles are very long the labrum covers some parts of mandibles. Labrum is covered with many long setas. Maxillae are a little more anterior than what we have seen in the workers. As a result of these big mandibles, labium appendages are in contact with them. To cut the long story short, because of this mouth structure, eating by them is impossible. So, they always need workers to feed them. Feeding by workers resulted in small less complicated labium and maxillae in soldiers in compare to workers. Postmentum is the most important difference between soldiers and workers, if the head is looked from ventral perspective. Though the soldiers' frons is not protruded as much as can be seen in the workers, but antennas are coming out from the antennal socket. As like as workers that were blind, soldiers also are. And, they have the pigmented cells near their antenna.

Antennas are smaller than what we see in the workers, 16 or less. As what we have observed in some of the soldiers, number of the segments is vary between two antennae. One of the feelers is sometimes smaller than another one (Fig.6).

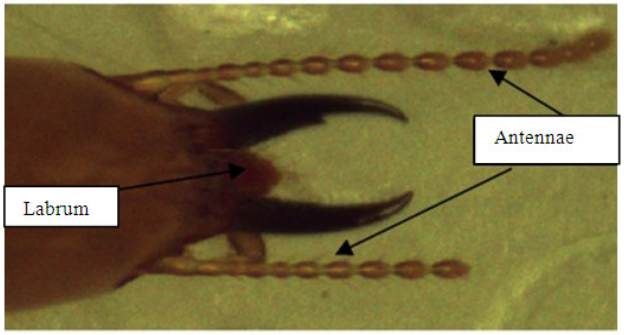


Fig.6. Antennae and labrum in Soldiers, *O. formosanus* Shiraki

Thorax

Although, soldier's thorax is very similar to that of workers, it is a little extended and larger than them. Pronotum decoration is the most visible thing in the thorax. Its saddle shape gives a special beauty and nobility to the body.

Legs

All the segments have been seen in the workers legs can be seen in soldiers' legs but in bigger size.

Abdomen

In compare to worker abdomen, it is not very hump shape and less curved. In usual, 80-90 percent of the abdomen is yellow and rest of it is black in color. This black color is the remaining foods in the digestive system. Whitish fats can be seen clearly all over the abdomen. Sternites and tergites have too much overlap that sometimes is difficult to draw a line between two sternites.

Fig.7. Total perspective of Soldiers, *O. formosanus* Shiraki. Body length is vary between 4.0-5.3mm

The lateral membrane is decorated with gates of spiracle that are a little protruded out. Cerci in the last sternites are smaller than what I have seen in the worker. Last sternite is covered by sensillae. A total perspective of soldier can be seen in Fig.7.

E. Alated or Winged

Head is completely pigmented in the alated. In except to clypeus that is a little brighter and protruded in compare to other parts of the head, head is looking black in color. Watching the head under the microscope gives some more details about structures. Sclerotized head is not smooth as what is observed in the soldiers and workers. Some dotted structures came out of the head and distributed all over the head. Moreover, the head is covered with long bushy sensillae. These sensillae are even more on the labrum.

Eyes

In addition to two pigmented area at the side of clypeus, the most important structures that cannot be seen in soldiers and workers is the compound eyes and two ocelli or simple eyes. Two black large compound eyes are located on top and side of the head. The eyes are very big as if looked under the microscope; corneal lens of sensory units or ommatidia can be seen easily. There are two ocelli near the eyes, lateral, but the median one is lost in termites. Though, duty of these ocelli still need more research, but it seems that these ocelli cannot form an image. They may only responsible for perceiving the light from environment (Fig.8).

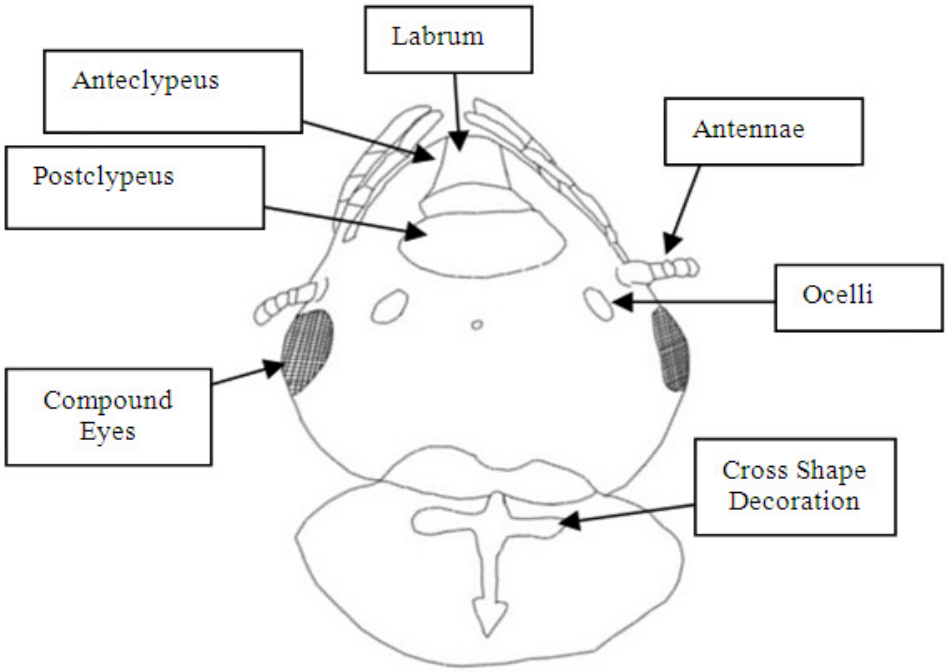


Fig.8. Alated head in *O. formosanus* Shiraki and its segments

Antenna

The antennas are bigger and more pigmented than that of worker. In addition, the segments are small and more dense in compare to worker ones. It seems the pedicle is shrinked or completely absent in the antenna. Number of the segments (Pedicle and scape are included) in the feelers are 19. As the feelers are sensory part of the body, long feelers may help both female and male to find the best partner for rest of their life.

Mouthparts

There are a few differences between mouthparts of worker and alated.

Thorax

This part of the body is extended very much in the alated. Pronotum shrinked and a little covered the head with bushy sensilla. The color is as similar as head, black. One straight yellowish line is passing along the thorax and in the center. The first segment of the thorax is a little stand out. A cross of brown lines (┼) in the first segment is giving a special beauty to the first segment (Fig. 8). The second and third segments of thorax are flat and more extended than the first one. Locomotion is very important in the alated. First segment of thorax is source of one pair of legs. In second and third segments in addition to legs, there are two pairs of wings. Forewings are always 2mm longer than hindwings; about 17.5 and 15.5 respectively. Flying needs spending energy, so, thorax is mostly filled with fat and muscles (Fig. 10).

Legs

Although, the legs are basically as similar as worker but there are some differences. For example, legs junction to the body is very strong and full of muscles. And, the legs are covered with long spines and it can be seen very clearly around tarsus. As chemo receptors are in high numbers in tarsi [10], may these spines have a very important role in feeling and sensing of male or female in both sexes.

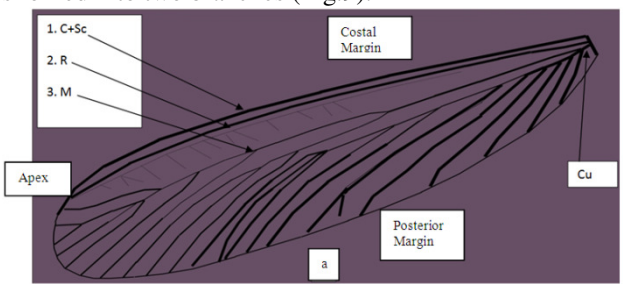
Wings

Wings are very important in taxonomy of insects, as we can see, Black wing termites has given to *O. formosanus*

Shiraki because of their wing color. However the name is black but the wings are not as black to not be transparent. They are in fact dark brown to black in color. They have attached to second and third segments of thorax.

Based on Comstock-Needham system, three parts can be seen in the wings, costal margin, apex, and posterior margin. The veins also are known by different names based on this system, Costa (C), Subcosta (Sc), Radius (R), Media (M), Cubitus (Cu), Anal veins (A), and jugal vein(J). It seems that Anal veins and jugal vein are absent in the termites wings [11, 12].

Costa is the first longitudinal vein of the wing. It is not branched in the termites' wing. Subcosta is the second longitudinal vein and it is fused with Costa. The third longitudinal vein is Radius that is in a very close distance with Sc and there is no branch in it. The forth one is Media, the most extended vein in the wing, which at first divided into two branches media anterior and media posterior. Down the wing media anterior forked into two more branches, on the other hand, media posterior makes four branches at the end. The Cubitus is the fifth vein, its branches are dark and thick that can be seen clearly under the microscope. In fact Cu is divided into two thick veins at first, but these two are get together again in middle of the wing. Except the first one that is not complete one, there are more ten branches from Cu that the only last one is forked into two branches (Fig.9).



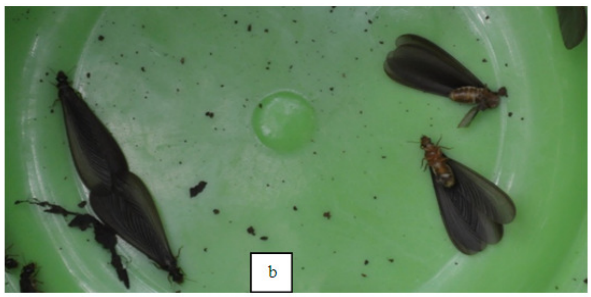


Fig.9. (a) Venation patterns in *O. formosanus* Shiraki's wing .Costa (C), Subcosta (Sc), Radius (R), Media (M), Cubitus (Cu). (b) Alated termites

Abdomen

Sternites and tergites are completely clear in the reproductives; Brownish-black sternites in the ventral and black tergites at dorsal part are separated completely. First three sternites have a whitish part in them that from first one to third on gradually decreased. Lateral membrane is white and fattish. Something interesting about the lateral membrane was that mouths of tracheal system or spiracles are visible under the microscope. Abdomen is a little curved as it goes toward anus. And anus is in the between last tergite and sternite. Cerci are not developed as what we have seen in the workers and only lateral cerci are available and central one is shrinked that cannot be visualized (Fig. 10).

Due to gender characterizations abdomen is a very critical part of the body in the alated. Female sternites are larger than the male one. In usual the total body length of female is bigger than male one a little bit, it is not too much to be considered as a male or female characteristic. Seventh sternite in the female one is stretched a little more in the way that eighth and ninth sternites are covered. In contrast with female, the male sternites are more packed and styli can be seen at the end of ninth sternite (Fig 11).

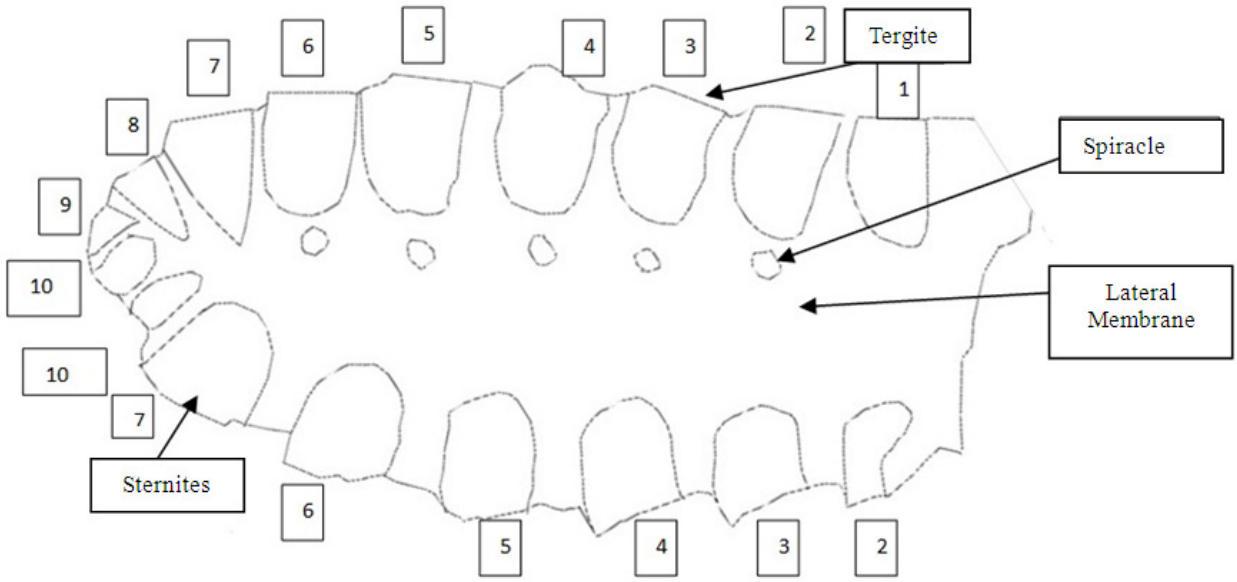


Fig.10. Abdomen and its segments in alated, *O. formosanus* Shiraki

International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473

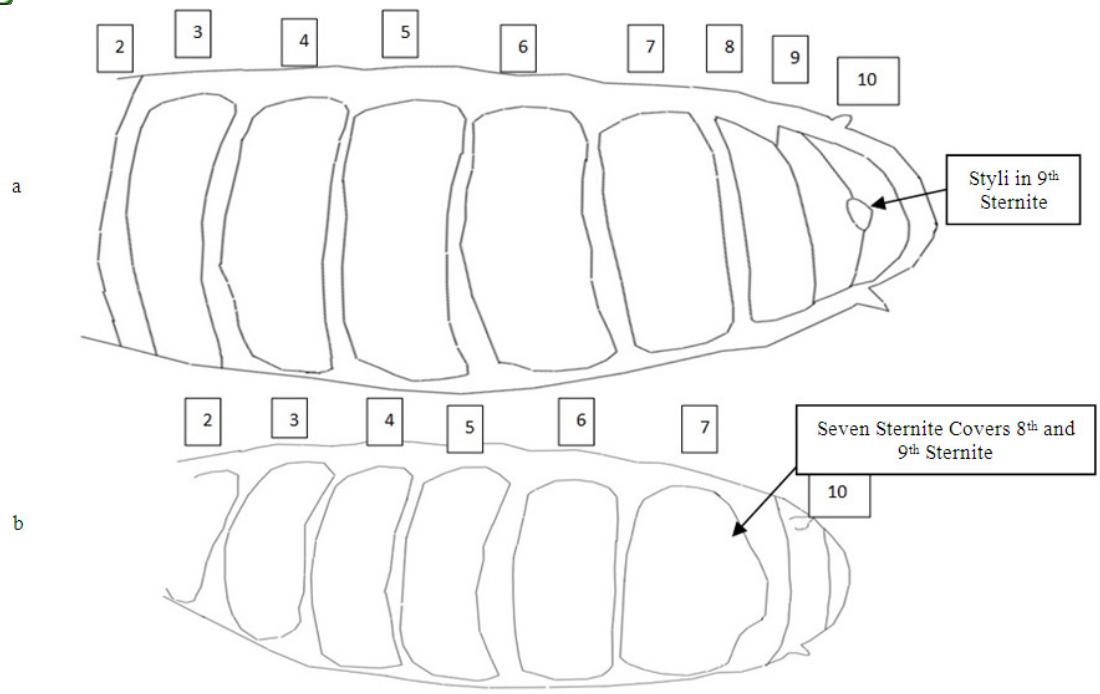


Fig.11. Difference between male (a), female (b) in alated, *O. formosanus* Shiraki.

F. King and Queen

After swarming and landing the alated will have shed their wings and start to find their partner. Then they will search for a crack in a wet trunk of a tree or damp place to make nest and from now on they will be called queen and king. After some years the queen abdomen will be extended and she loses its ability to move in harmony. Sometimes the body length of the queen will reach more than 6 cm. And abdomen is more than ten times bigger than length of thorax and head together. The king's body on the other hand, is as similar as alated but a little puffed and does not exceed more than 1cm. (Fig. 12).

Fig.12. Queen (a) and king (b) of *O. formosanus* Shirak

Queen's head and thorax are completely similar as alated, eyes, ocelli, mouthparts, antennae, legs and thorax segments all are similar as alated. The last segment of thorax in queen is looking smaller because the abdomen is extended and covers some parts of this segment. In exception to sternite lines that cross the abdomen and are in brown color, the abdomen, in dorsal and ventral, is like a mass of whitish smooth tissue. Sensillae only can be seen on the sternites line and cerci became very small due to the sternite extension.

Lateral membrane is covered with pigmented cells and is not as smooth as dorsal and ventral parts. Something interesting about lateral membrane is the mouths of tracheal system can be seen easily even without microscope.

IV. Conclusion

Morphology is the basic work in insect taxonomy and insect recognition. Wang 1985, Zhuo 2004, Tong and Dai 2004, Xu et al. 2007 classified the soldiers based on their sickle shape mandible or tong shape labrum [2]-[3]-[4]-[13]. In another study by Zhang et al. 1993, Liu et al. 1985 alated are recognized by their obvious physical features [5]-[6]. One of the most important works on *O. formosanus* Shiraki has done by Zhu-Ge et al. (1978) [1]. He classified the workers, soldiers and larvae based on their biometry of head and body. He even gone further and put the soldiers and workers into minor and major groups based on their head width. We also have classified workers and soldier of *O. formosanus* Shiraki into different groups based on their foraging activities [14].

Although, this research shed light on many dark sides of *O. formosanus* Shiraki, but many questions remain to be answered. Embryogenesis and morphological changes of embryo and gene expression during this period can be interesting topic for future research. MicroRNAs expressions during different instars of larvae is another question must be answered during next research. Workers and their complicated role in the nest make them very interesting for scientist. For example, is there any kind of workers that only remain in the nest and never go for foraging and only their work is to take care of nest and fungal garden. Soldiers usually can be seen in a few during foraging. It surprises me that may soldiers in *O. formosanus* Shiraki are as similar as *Nasutitermes*

corniger (formerly *N. costalis*) and they first find the food then they recruit the workers to the source of food [15]-[16]. In fact the soldiers may play the role of scout in foraging and the worker do the rest of works. In addition we have found that ratio of females in the alated are more than males. This can be a good question whether the *O. formosanus* Shiraki can be classified between the asexual queen successions (AQS) species. In this case queen can save its gene for eternal by asexually producing another queen [17].

ACKNOWLEDGMENTS

We thank professor Ding Yulong for his kind supports. We highly acknowledge all the professors and students in Nanjing Forestry University who helped us in this paper.

REFERENCES

[1] Y. Zhu-Ge, J. L. Wei, Z. X. Zheng, R. D. Lin, "Preliminary analysis of larvae instar and type differentiation for Odontotermes formosanus (Shiraki)," Journal of Disturbed State University, vol.3,1978, pp.65- 70.

[2] Z. F. Wang, "Morphological identification of Odontotermes formosanus and Macrotermes barneyi (Isoptera:Termitidae)," Journal of Zhejiang Forestry Science and Technology, Vol 2, 1985, pp. 38- 40.

[3] Y. Zhuo "Study on morphological characteristic of five kinds of termites and Macrotermes barneyi Light biological characteristic in Hunan," Hunan: Agricultural University of Hunan, 2004, pp.1- 28.

[4] Z. D. Xu, D. Y. Li, G. Q. Zhou, J.D. Xiong, Z.N. Huang, "Biological characteristics and integrated control technology of Odontotermes formosanus (Shiraki)," Bajing:Chinese Bulletin of Entomology, 2007, vol.44, pp.763- 769.

[5] Y. Z. Liu, G. Q. Tang, Y. Z. Pan, L. D. Chen, Y. Z. Hem "Observations on the reproductive caste of Odontotermes formosanus (Shiraki): larval development and naptial flight," Acta Entomol, vol.28, 1985, pp. 111-115.

[6] F.Y. Zhang, C. Li, Q. K Gao, "Scanning electron microscopic studies on wing microsculpturing of Odontotermes formosanus and Macrotermes barneyi (Isoptera : Termitidae)," Zool Res, vol.14, 1993, pp.270, 269, 282.

[7] J. Hu, J. C. Pan, W. Y. Tan, J. H Zhong, M. Guo, Z. Y. Huang, J. Q. Li, B.R. Liu, "Structure of the compound eye of alales Odontotermes formosanus," Chinese Bulletin of Entomology, vol. 46, 2009, pp. 272-276.

[8] B. H. Cai, N. S. Chen, A. G Chen, Z. H Chen, "The nest structure and development of Odontotermes formosanus (Shiraki)" Acta Entomol, vol.14, 1965, pp.53-69

[9] A.S. Lin, "Study on the integrated pest management technology for termites damaging in landscape plants" Zhejiang: Zhejiang University, 2009, pp.1- 91.

[10] M. F. Schneider, "Entomology, A textbook for students, Agriculturalists and Foresters Student in Papua New Guinea," 1st ed, Papua New Guinea: Bulolo University College, 1999, pp.12- 30.

[11] A. E. Emerson, "A review of the Mastotermitidae (Isoptera), including a new fossil genus from Brazil," Am Mus Novit, vol.2236, 1965 pp.1- 46.

[12] M. S. Engel, D. A. Grimaldi, K. Krishna, "Termites (Isoptera): their phylogeny, classification, and rise to ecological dominance," Am Mus Novit, vol. 3650, 2009 pp.1- 27.

[13] X. W. Tong, X. G. Dai, "Summarizing of research and control of termites in Hunan" Hunan: science and Technology Press, 2004, pp.4-20.

[14] E. Soleymaninejadian, B. Z. Ji, S. W. Liu, J. J Yang, X. W. Zhang, "Foraging Polyethism in Odontotermes formosanus Shiraki," JOAAT, 2014, to be published.

[15] J. F. A. Traniello, "Enemy-deterrence in the recruitment strategy of a termite: soldier-organized foraging in Nasutitermes costalis" Proc Natl Acad Sci USA, vol. 78, 1981, pp.1976–1979

[16] E. Soleymaninejadian, B. Z. Ji, S. W. Liu, S. L. Ji, J. J. Liu, "Polyethism in Termites," AE, 2014, to be published.

[17] S. C. Jones, J. P. LaFage, R. W. Howard, "Isopteran sex-ratios: phylogenetic trends," Sociobiol, vol. 14, 1988, pp.89–156

AUTHOR'S PROFILE

Ehsan Soleymaninejadian

born in Esfahan, Iran (11th of july 1983). B.Sc. in Biology (zoology), Gorgan university of Agriculture and Natural resources (2007). MSc in Biotechnology (mesenchymal stem cell), Jawaharlal Nehru Technological University of Hyderabad and Natinal institute of Technology (Roarkela) , India (2011) . Ph.D. in insect physiology (polyethism in O. formsanus Shiraki), institute of Forest protection, Nanjing Forestry University of China (2015).

His most recent publications are (Corresponding Author): J. Asadi, A. Golalipour, E. Samadian, E. Soleymaninejadian, M. K. Telori, H. K. Fathi, "Association between ATTG insertion/deletion of NFκB1 (rs28362491) Gene Promoter and Coronary Artery Diseases," IJRDET, Vol.2 no.2, pp. 125-129. 2014. E. Soleymaninejadian, A. Movahedi, C. Jiang, S. Chen, "MicroRNAs and Chemokines can Make Biomimicking Structures such as Liposome and Membrane Engineered Vesicles More Efficient in Gene Delivery," Open Access Scientific Reports. Doi:10.4172/scientificreports.762. 2013. E. Soleymaninejadian, K. Pramanik, E. Samadian, "Immunomodulatory properties of Msenchymal Stem Cells: Cytokine and Factors," American Journal of Reproductive Immunology, vol. 67: pp.1–8. 2012.

Mr. Soleymaninejadian currently working on polyethism in *O.formosanus* Shiraki. He got Jiangsu Governmet Scholoarship for his work. His major interests are immunology, immunotherapy, drug delivery using liposom, stem cell therapy.

Mr. Ehsan Soleymaninejadian is reviewer of Biomedical Journals (OMICS publication groups).