Excavation and Architectures of *Odontotermes formosanus* Shiraki Nests

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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 Myanmar, and Vietnam. 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. In this paper we first given a method to dig the nest of O. formosanus Shiraki and then studied the architecture of O. formosanus Shiraki nest based on the soil layers. We found the soil compositions have a key relation with architecture and depth of the nests. The thicker top soil becomes the more eagerness for queen and king to build their nest deeper. In fact the main fungal garden with queen and king is placed on the subsoil where the soil is more stable with higher amount of clay in it.

Key Words:

Isoptera, Termites, *Odontotermes formosanus* Shiraki, Nest excavation

Introduction

Termites are social insects and they make colonies. Different casts have different duties in the nest. There have been published many papers in establishment and maintenance of the nest. Lüscher studied the mound structures during 1951 and 1956 while Weidner (1956) has done a great research on Macrotermitinae nest architecture. Beauty of the nests' architecture both in mound builder and Macrotermitinae have been demonstrated by Noirot (1970). Macrotermitinae are usually subterranean termites and they build their nests under the ground, in spite, the other species such as Macrotermes making mound structures. These above ground structure of termite will help them to survive in very dry areas; when other species are going deep into ground because of sunburn (Turner and Soar 2008); termites are active above the ground with their mound structure. Mound can be seen in different sizes and sometimes they reach nine meter above the ground (Noirot and Darlington 2000). Mound structures of termites remind the wind catchers of Yazd, a Persian city. There are many similarities between mound and windcatcher in Yazd. As like as windcatcher in Yazd they act like an air condition for the nest. Air can blow in lower chamber easily by the means of the tunnel that surprisingly engineered by termites in the structure. In contrast with the mound maker termites, generally, the nest is made underground. They can be found near a tree or fallen timber. Polycalic nests are very common in Microcerotermes and some other species. These nests are very complex; it means if one nest is destroyed another one takes the place. It is very important in the case pest management, because by destroying one nest should not be thought the termites are gone. From these nests there will be some shelter tubes that take the termite to the source of food such as dead wood (Takuya et al. 2000). In usual, the termites nest is known as a fungal garden (Ohkuma 2003). They cultivate Termitomyces, and use their excrement to nourish the Termitomyces. These fungi will have been eaten by workers, but the spore will be undamaged in their digestive system and can grow in their feces again in the nest (Donovan et al. 2001). Feces are one of the important parts of the nest breaks. In addition to feces, mud, chewed wood, soil are the building blocks of the nest (Eggleton et al. 1996). The nest is not an only protective chamber for termites; there are many other purposes for the nest (Eggleton et al. 1996). One of the most amazing phenomena in the nest is Co_2/O_2 balance in the nest. The nest engineered in a way to make balance between CO_2 and O_2 (Sands 1969). Moreover, the moisture in the nest is controlled in some parts by special structure of the nests and chambers (Turner and Soar 2008). There are many nursery rooms for hatching egg and larva. Fungal gardens are all over the nests and sometimes the nest is known as a fungal garden (Traniello and Leuthold 2000).

In this paper *O. formosanus* Shiraki nests, a subterranean termite, and their behavior to make nest have been studied. Soil composition has a very key role in the nests architecture. Four different nests excavated and depth, soil and architecture of the nests examined.

Materials and Methods

1. Field investigation-to find the nest

Campus of Nanjing Forestry University and Zijin Shan Mountains has been investigated to find perfect places for digging the nest. 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), was the study site. Hot damp summers and cold damp winters with short spring and fall are the main characteristic seasons in Nanjing.

1.1 Find the place the termite appeared last year by the soil traces on the trees left by mud shelter tubes falling off.

Last year in the warm months of the year (Jun.-Oct.) it was possible to see termites' shelter tubes on trunk of host trees. That was a good sign to trail termites' nest. The shelter tubes must be followed until getting to the ground. It must be known that not all the shelter tubes are ending up with termites. Some of them are fake tubes to confuse the predators (as well as us) and others are discarding ones. Fresh shelter tubes are usually covered with wet mud shelter. So, founding wet shelter tubes is a good sign of foragers and main shelter tubes. And dry shelter tubes with foragers are commonly hard to be broken. On the other hand, labyrinths wall are not much thick and usually break easily. In March and first half of April the temperature is in a range 5-23°C, temperature is changing quickly even during day time, in Nanjing , so, it is not possible to see shelter tube on the trees. Even though, we can find the soil signs left by the shelter tubes falling off. The foraging range and approximate nest location can be determined according to the soil traces. At the end of April the temperature increasing and foragers start to make shelter tubes on the bark of the trees. Making a breach in the shelter tubes using a tweezers make the workers and soldiers exposed (Fig 1).

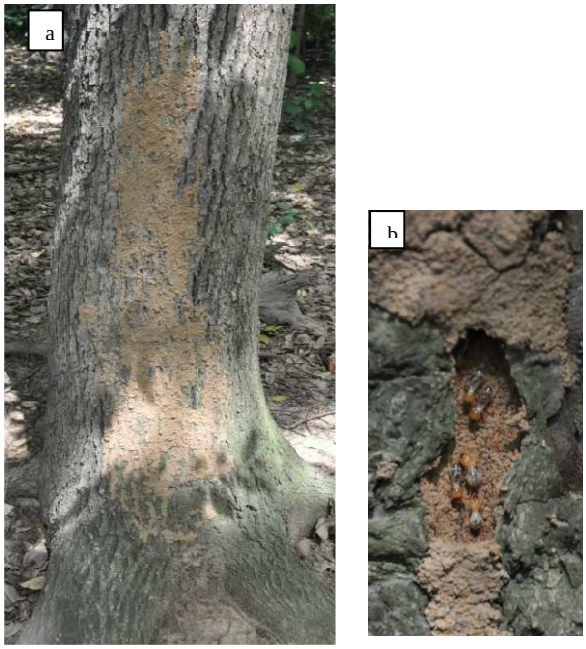

Figure 1: Above picture is showing the infestation by *O. formosanus* (Shiraki). a) The tree is covered with mud shelter tubes. The new shelter tubes can be recognized by wet mud on the trees. b) A little breach on the shelter tubes make the termites exposed to the environment. The tubes helping them to be protected against predators and light.

1.1.2 Find the foraging activity signs under the fallen logs

After discovering the place the termite appeared last year, we need to narrow the searching scope. Rotten logs are the most favorite food for them in this time of the year. It seems in this time they are warming their digesting system with rotten cellulose. The rotten logs have been degraded by wood-rotting fungi and are getting easier for termite digestion. March in Nanjing, the weather is not so cold and some of workers come out of nest to forage foods. Dry last year fallen logs can be the best target to the termites. As the logs moved if the rotten smell felt, that has the highest chance to get the termites. Usually the bark is in attached with ground soli. It means the logs left untouched and without disturbance for a long time. In addition, the termites don't like the new fallen barks with grasses under them. If we find the foragers under logs, it means there is an active colony nearby (Fig 2).

Figure 2: A Rotten fallen log that is a good target to find the foragers under it during spring. Special smell due to fungal activities stimulates the olfactory cells. Normally another species of termite, *Reticulitermes* spp, may see with *O. formosanus* (Shiraki).

2. Determine the site of nest according to the ants or other predators

Ants are the biggest enemies of termites, if ants' nest found around, it means termites are not living around.

3. Species identification

In usual no other visualized species of insect are living at the foraging site of them. However in some cases we have seen other species of termite such as *Reticulitermes* spp. are living in proximity with *O. formosanus* Shiraki (Fig 3).

Figure 3: Difference between two species of termites. a) *Reticulitermes* spp that is pale whitish in color and very active during the spring on the rotten barks. Normally they can penetrate deeply in the logs and sometimes can be found in the pith and heart wood of trees. b) Foragers of O. formosanus Shiraki after a break in shelter tube. The yellowish color of head and black and white abdomen are the characteristic features of this species. Their soldiers' special sickle shape mandibles also can be good criterion to recognize them from other species.

4. Digging the Nest

4.1Find main tunnel according to mud shelter tubes or foraging workers under rotten timbers

Main shelter tubes on trees or track of workers under the bark must be followed until getting to the ground. This labor work should be done after a rainy day. In fact the soil must not be dry and not be a mud. It is better to temperature be around 15°C or lower. As we don't need an active nest to get all the possible samples. If samples needed out of the nest, for example foragers, it is better to do the excavation in higher temperatures. As the source of foods is far from nest, there are some main tunnels to connect the source with the nest. In usual the main tunnels go to the chamber directly. It must be considered that the location of foods changes continuously, some of tunnels are discarded (the false tunnels). It increases the complexity of tunnel system. At the time of attacking by ants or other termite species they use these tunnels to scape or confuse the enemies. For us as the diggers also can be very confusing to find the in-use main tunnel. However the main tunnel usually crowded with workers and it can be a good sign to not be confused with other galleries. The main horizontal tunnel most be followed by removing the soil till get to the vertical tunnel. Diameter of this

vertical tunnel is bigger than horizontal one. From now on the digging must be quick with high cautious. A thin branch of bamboo shoot had been used to not lose the foraging and main tunnels. As digging went forward the bamboo shoot penetrated more into the tunnels and then the digging continued. If the tunnel is the main one usually dead soldiers and dead workers can be seen that stick to the shoot while pulling it out from tunnel.

4.1Find the chambers

The soil around the nest is very hard to be dug and this part is Achilles hill of the work. Sometimes digging it roughly makes some damages to the interior part of the nest. So, the work must be very fast, whilst with high cautious. Delay in digging the nest means losing the queen and king and also losing the opportunity to catch each group of workers in their right positions (if needed). Based on maturity of nest the main nest containing different numbers of fungus combs. Young nests have a monochamber with royal chamber at center toward bottom. In the case of old nests, many fungus combs or fungal gardens can be seen, some of them are small and some are big. The big one is usually the main fungus comb and queen and king chamber (royal chamber) was located in it. Reproductives chamber (queen and king chamber, royal chamber) must be seen in the center of main fungus comb. There must be some holes on the wall of royal chamber, which connect queen chamber with the fungus combs in the main nest and passing through them, minor workers feed the parents and take the eggs out of royal chamber. Then eggs may be delivered to other chamber for hatching. If many eggs have not been transferred, eggs and busy larvae and workers may cover the outer layer of the royal chamber.

Results and Discussion

Four kinds of nest we found in the Nanjing Forestry University campus, a big mono fungal garden with queen and king chamber at the bottom of it, multi fungal garden with queen and king chamber at the bottom of the biggest and deepest (in soil) fungal garden, small monofungal garden with queen and king and small multi fungal gardens.

It is necessary to mention that structure of the nest usually depends on the soil structure. As we have found the queen and king chamber is in most protected part of the nest and at the bottom of fungal garden. They usually go down as deep as possible to get to a sticky stable clay soil or subsoil. In addition the structure of the soil gives the structure of the nest. For instance if the queen and king reach to the clay and stable soil not very deeply they start to build their nest superficially (as deep as finger knuckle) and the tunnels connecting the fungal gardens also are not very deep(Fig 4). So the nest will extend horizontally and usually fungal gardens are not very big.

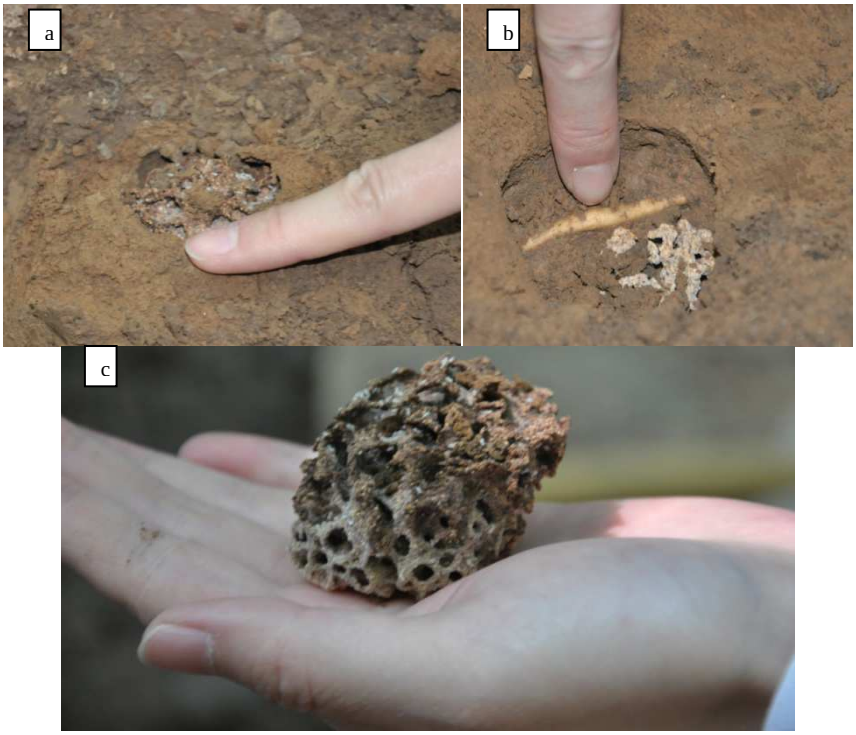

Figure 4: *O. formosanus* Shiraki nest always does not need to be dug deeply sometimes the nest is in the surface especially when the top soil is very thin. a) As it can be seen superficial nest both in mono fungal garden or poly fungal garden are not big in width, smaller than a normal finger. b) The nest normally made in top soil with high amount of humus and root of the trees. The depth of the fungal garden sometimes is smaller than a knuckle. c) After removing the fungal garden from soil the total fungal garden is smaller than a normal hand palm.

In addition we have found that if the soil is not tough and is full of compost the queen and king more interested to build their nest at deeper part of the soil until they get to subsoil. In this case the fungal gardens are bigger. Two nest structures we seen when the nests have built in deeply. First with a big extended main fungal garden and without any peripheral fungal gardens which the queen and king chamber was at the bottom of the garden, fungal garden is more oval shape then circular shape. And second with a bigger main fungal garden and some smaller peripheral fungal gardens. Subjected to this, fungal gardens are more circular and usually peripheral fungal does not have any eggs. All the eggs were concentrated on the main fungal garden. Existence of larvae on the peripheral fungal gardens was depending on the number of them in the nest. If they were too many of them, they used to see in peripheral gardens also, whilst if the number of them a few they all live near the queen and king chamber on the main fungal garden. In contrast with fungal garden that made of feces and dead bodies and decayed wood the queen and king chamber is made of mud and the compositions of it probably coming from subsoil. Sometimes it is possible to see rotten old fungal garden that left long time back by nest. The color of this left garden turns to black and sometimes the distance between the old one and the new fungal garden is 30 cm. In addition to the fungal gardens, main fungal garden, and old rotten fungal garden there are some empty room that it seems they are going to be used for construction of coming fungal

gardens. The soil around the fungal garden and main fungal garden and empty rooms all are made of sticky sub soil and the dark brown color of the soil around these structures is completely different than the upper soil with lot of humus. Even the fungal gardens are made of different layers and the colors of layers are different. The upper layer is dark gray, then a thin brownish layer that is border between upper layer and middle layer. Next is middle layer with gray color and then a layer that is around the queen and king chamber (bottom layer). The bottom layer is very thin and is sometimes is difficult to find a border between middle and middle border; however by little force they can be separated. This is may important during handling the main nest specially when it is going to be taken out of soil; as the fungal garden is very fragile and the intact fungal garden needed, it is better to remove the garden with high cautious (Fig 5,6).

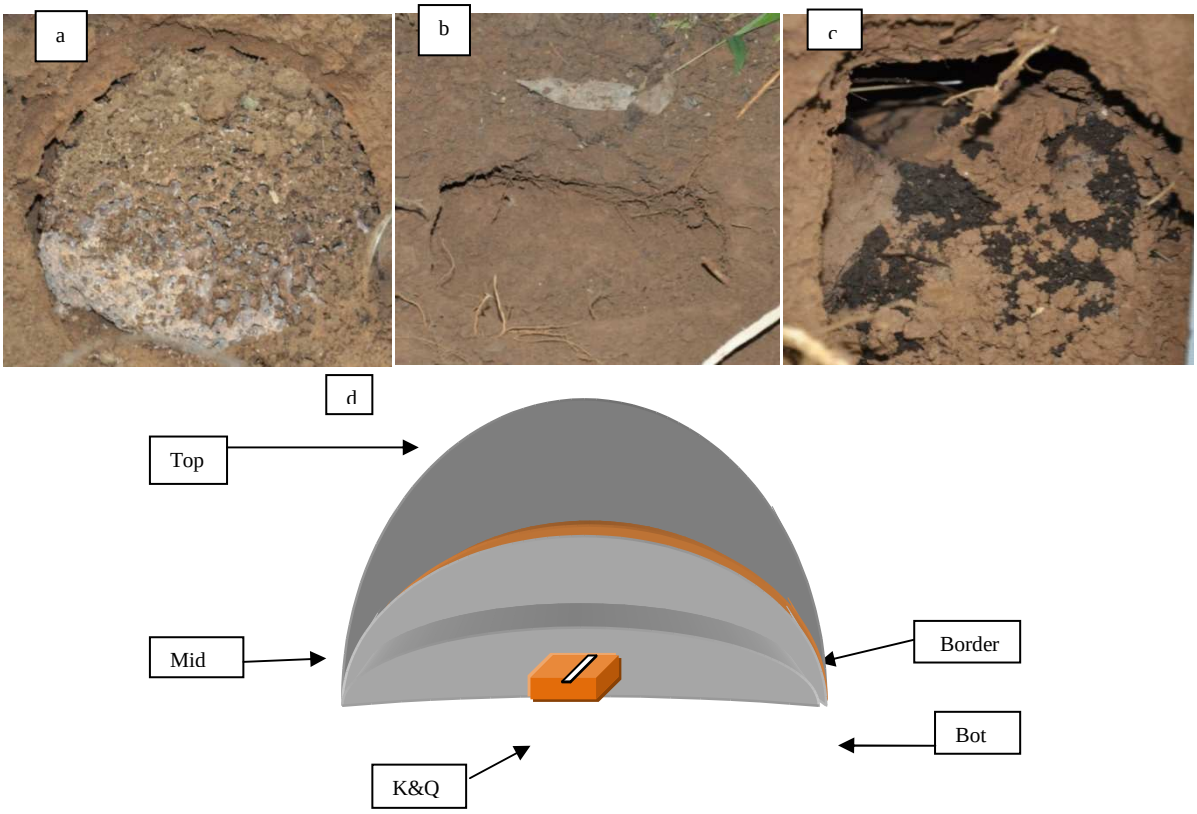

Figure 5: Different structures that can be seen in a nest. a) Fungal garden, width of a fungal can be vary between 4-12 cm and the height can vary between 3-14 cm, b) is an empty cavity that probably the new fungal garden will be assembled in the cavity, c) old rotten fungal garden that the color of the garden is turned to black and sometimes the distance between the old one and a new fungal garden is 30 cm. d) Different layer of a fungal garden, Top, middle (Mid) and bottom (Bot) of a fungal gardens with a clear border between top and middle layer and not clear border between middle and bottom border. King and queen (K&Q) chamber is in attached with bottom layer and there was a gate that soldiers and workers could transfer between the chamber and bottom layer. The gate has shown on king and queen chamber (white color) in the picture.

Distance of foraging site to the main nest was depended on the density of the trees it can be vary between 10cm- 6m. O. formosanus Shiraki liked to build their nest very close to the source of food. Normally it is not more than 1m. However during the spring time when the trees are still dormant the foragers show interest to the decaying logs specially those that have a little connection with soil or even covered with soil. Sometimes the smell of stale is coming out the decomposing fallen bark. In this case may the site of foraging increase a little more than 1m. During the summer the distance, nest-foraging site, is very short and normally lees than 1m.

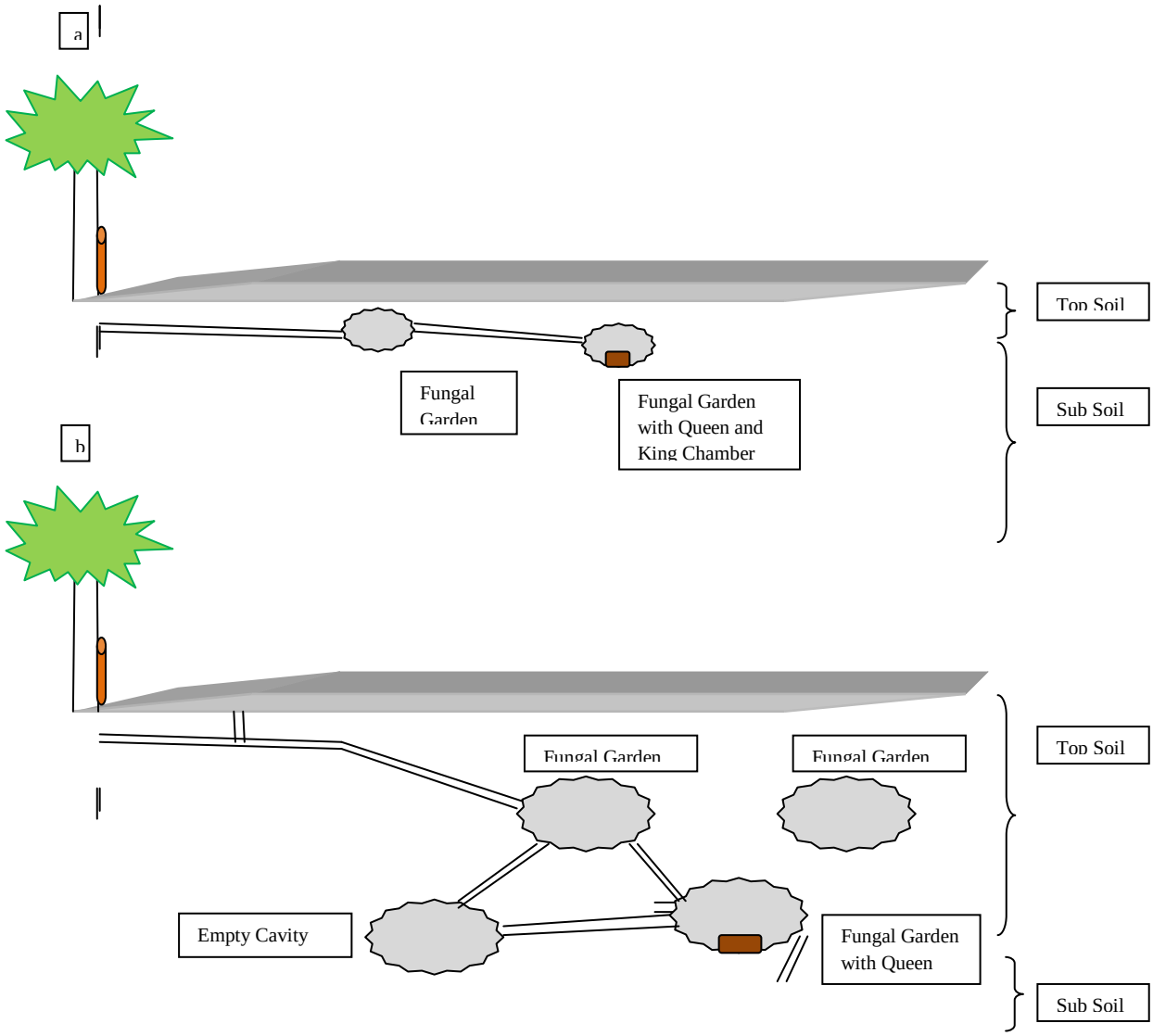

Figure 6: Two different nest architectures based on the soil structure can be seen in this schematic picture. a) When the top soil that contains humus and root of plants is very thin (less than 10cm) and the subsoil is very close to the surface of the ground the fungal gardens and the main fungal garden with queen and king assembled very near the

surface of the ground. The nest in this case is extended through the horizon with small fungal garden as what can be seen in Fig 4. b) When the top soil is thicker, can be reached down to 3m, the queen and king are more interested to build their nest on the bed of subsoil. The fungal gardens are very big and the nest extended vertically. It needs to be mentioned that it does not matter if the nest is mono or poly fungal garden. Subjected to mono fungal garden the architecture will be similar only with one fungal garden.

Some points must be considered during digging the nest. First of all, it should be considered that as digging move forward, the number of soldiers will be increased; the most abundant numbers of soldiers are around queen and king chamber. Next, the smell of fungal garden can be a good guide to find the main nest. And, soil structure also is good sign of getting closer to the main nest. Soil structure around the nest is more packed and needs more efforts to be removed and digging operation may become slower. And the last but not least is that as the digging operation going closer to the fungus combs, the more care must be taken; fungus combs are very fragile and digging force make break it down. In the older nests, positions of fungal combs in relative with royal chamber are as similar as solar system. If we imagine the royal chamber as the sun, the fungal combs can be imagined as other planets. However, this sun is not exactly located in the center!

Two kinds of methods for finding the nest of *O. formosanus* Shiraki have been explained by other entomologists, **t**he foraging activity signs (as what we have done) and *Termitomyces.* In rainy season the fruiting body of *Termitomyces* appears on the earth's surface. It is a good instruction for finding main chamber of the nest, but it can only suit for short time, rainy seasons, and mature nest (Zong 1978). However tracing the mud shelter tubes is a time-consuming and heavy work, but it suits all the foraging season except winter and early spring and different stages of nest. Zong (1978) had studied the relationship between mud shelter tubes and main chamber site. To find more surface signs and increase the locating accuracy is still an important issue.

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