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SEM Observations on the Predation Behavior of *Agistemus terminalis* (Quayle) (Acari: Stigmaeidae) and *Amblyseius sojaensis* Ehara (Acari: Phytoseiidae) on *Panonychus citri* (Mcgregor) (Acari: Tetranychidae)

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Abstract: The predation behavior of *Agistemus terminalis* and *Amblyseius sojaensis* on *Panonychus citri* was studied under scanning electron microscope. *Agistemus terminalis* grasped egg stalk by claws and sensory organ of palpi and direct attack on eggs was done by needle-shaped stylets extruded from the rostrum. A distinct hole was found on the egg surface produced by the penetration and successive withdrawn of the rostrum and stylets. Finally, the hole became wide by the further attack of rostrum and palpi. *Amblyseius sojaensis* predated on the larvae and adults of *P. citri*. It grasped the anterior portion of the prey body by palpi and legs. Several sharply pointed and bent setae of palpi invaded into the cuticle of the prey. The prey was then attacked by the chelicerae and the cuticle was lacerated. The drawing of body fluid occurred by the extended malae which were positioned between the corniculi and the chelicerae.

Key words: Chelicerae, grasping, piercing organ, predatory mites, rostrum

Introduction

Amblyseius sojaensis Ehara has been found on citrus plants in Japan as well as on Chinese black pine or cypress around citrus grooves and it is a possible factor of spider mites predation playing an important role in agriculture (Ehara, 1972; Inoue and Tanaka, 1983; Osakabe *et al*., 1986). *Amblyseius sojaensis* has also been reported to control *Panonychus citri* (McGregor) at low densities when tea pollen added on the plants (Osakabe *et al*., 1987).

Mites belong to the genus *Agistemus* are known to feed usually on phytophagous mites or scale insects (Ehara, 1964). *Agistemus terminalis* (Quayle) was found on citrus orchards of Japan by Summer (1960). It feeds on the eggs of citrus red mites (*Panonychus citri*).

The morphology of organs and characteristics of different appendages involved in the predation have been described in other mites (Macquitty, 1984; Akimov and Yastrebtsov, 1988; Zhavoronkova, 1990). The function of their organs during feeding have also been described (Evans and Loots, 1975; Evans, 1992). Although the cheliceral and deutosternal morphology of some Phytoseiid species was described by Flechtmann and Mcmurty (1992), it is not surprising to find a variety of mechanisms in different mites.

There are only scanty morphological information on the feeding organs and their behavior of phytoseiid mites. Similarly the stigmaeid mites were only recognized as predators of phytophgous mites (Ehara and Amano, 1995; Inoue and Tanaka, 1983). The functional structures of feeding organs in these mites have not been described and the feeding tract of *Agistemus terminalis* and *Amblyseius sojaensis* are also completely unknown.

This experiment was conducted to elucidate the morphology of organs used during feeding by *Agistemus terminalis* and *Amblyseius sojaensis* on the egg and adult of *Panonychus citri* (McGregor) under scanning electron microscope.

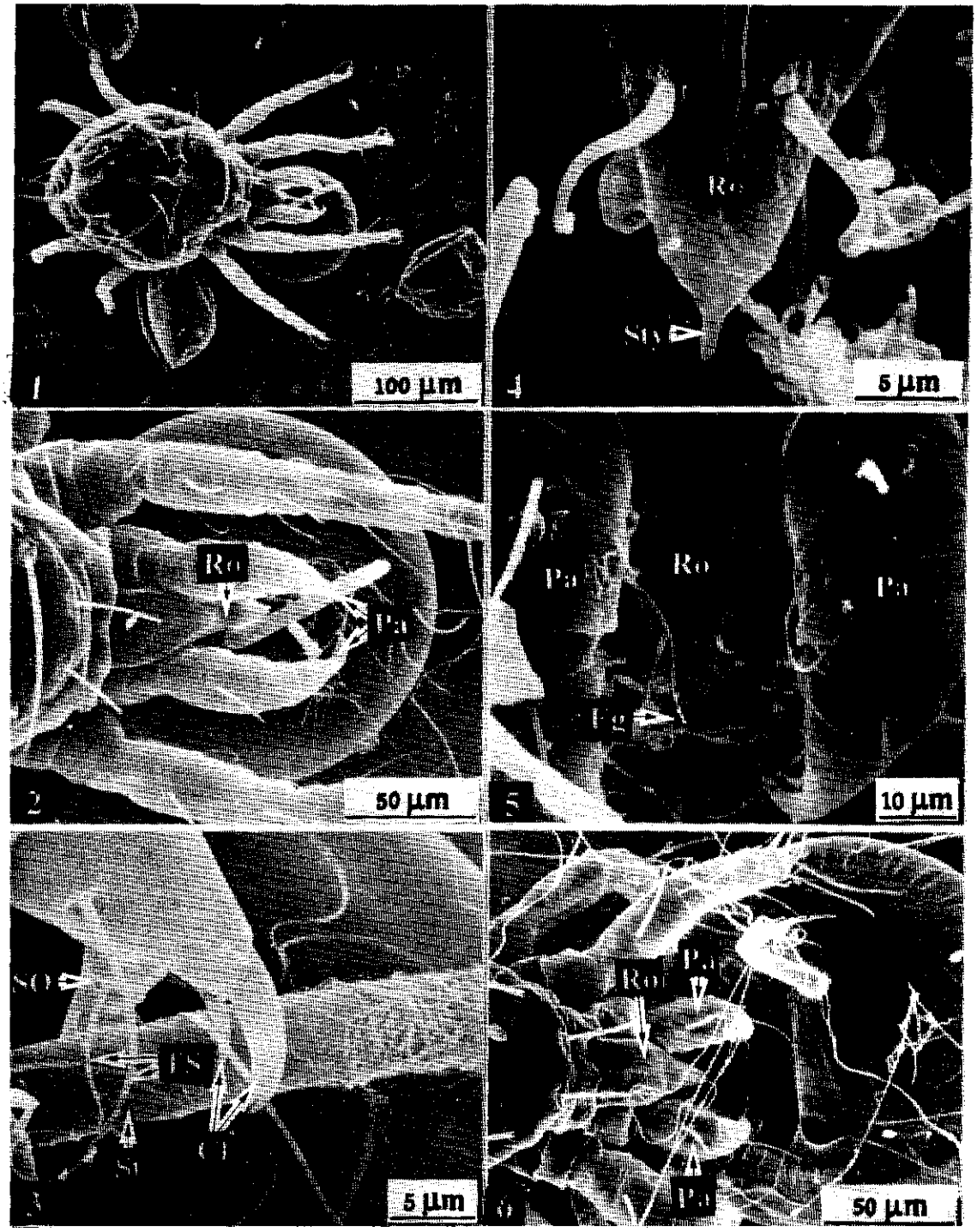
Materials and Methods

The experiment was conducted in the Citriculture Laboratory, Faculty of Agriculture, Ehime University, Japan. The citrus leaves infested by *Panonychus citri* were collected from the campus vicinity during August to December, 1998. *Agistemus terminalis* and *Amblyseius sojaensis*, both of which are predators of *P. citri*, were isolated from the collected leaves and were starved for 12 hours. They were then released on freshly collected leaves infested with *P. citri* and taken under observation by stereoscope. When a predator grasps and starts attacking on the prey, the leaf on which this phenomenon was occurring and was immediately dipped into the liquid nitrogen to freeze. Samples were pre-fixed in 6% glutaraldehyde in 0.1 M phosphate buffer in pH 7.2 followed by rinsing in the same buffer and were post-fixed in 1.5% osmium tetroxide. Dehydration was carried out with a graded ethanol series and were dried in a Vacuum Device Inc., VDF-20 freeze dryer. Dried samples were mounted on the specimen stubs, coated with gold using Eiko Engineering Co., LTD., 1B-2 ion sputter and finally were viewed under Hitachi S-2250N Scanning Electron Microscope at 20kV and photographed.

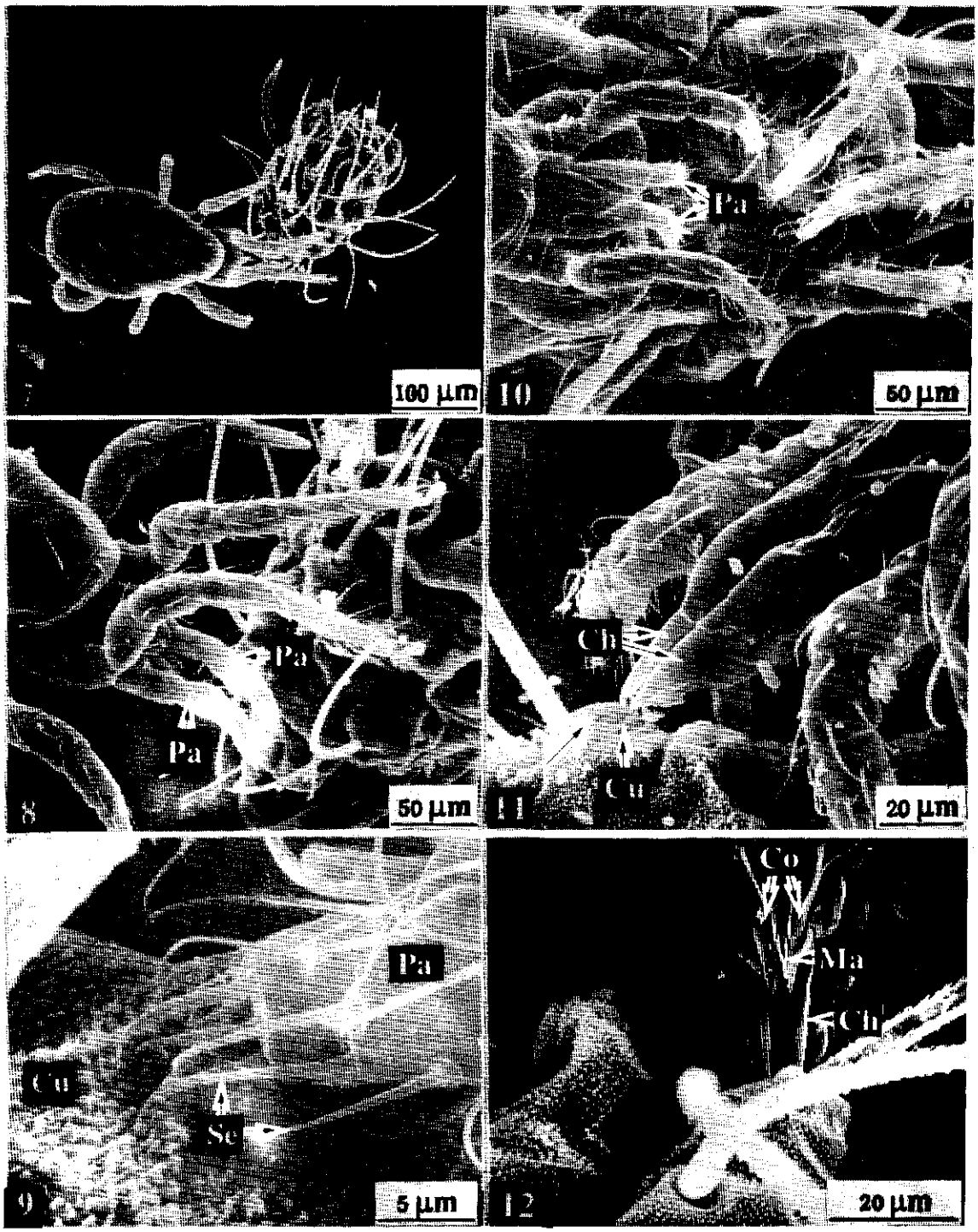
Results

Predation behavior of *Agistemus terminalis*: *Agistemus terminalis* fed on the fresh eggs of *Panonychus citri* even though the leaf surface was occupied by many other distorted eggs. The predator grasped the egg stalk of *P. citri* by its palpi and spread the forelegs along with the palpi over the egg (Fig. 1). The palpi (Pa) strongly griped the egg stalk and the rostrum (Ro) extended between the palpi on the dorsal portion of eggshell (Fig. 2). Claws (Cl) and sensory organs (SO) of palpi were used for grasping the egg stalk (St). The tactile setae (TS) of sensory organ were also found to be attached with the surface of the egg stalk (Fig. 3). Before attack, the rostrum (Ro) becomes ready by extruding the needle-shaped stylet (Sty) from the tip of the rostrum (Fig. 4). For charging on the egg, the palpi (Pa) and the rostrum (Ro) were used. The palpi were bent ventrally to keep the egg (Eg) fixed. The tip of the rostrum penetrated into the egg and made a hole on the surface (Fig. 5). This hole becomes more distinct when the penetrated rostrum was withdrawn from the egg. Feeding or sucking of egg contents occurred through the protruded stylets. The affected egg had a big hole on the top portion beside the stalk manifested by the palpi (Pa) in front of the rostrum (Ro). Palpi and the rostrum were pushed inside the hole for sucking the residual portion of egg contents (Fig. 6).

Predation behavior of *Amblyseius sojaensis*: *Amblyseius sojaensis* was found to attack citrus red mite from the anterior portion of prey by its palpi and legs (Fig. 7). The first and second pair of legs were involved for attacking and the forelegs being used for tapping on the dorsal setae and cuticle of idiosomal area of the prey. The palpi (Pa) pressed on the stylophore to immobilize the body of the prey (Fig. 8). The tips of several sharply pointed setae (Se) were



Figs: 1-6: SEM micrographs showing the grasping and feeding on the egg of *Panonychus citri* (McGregor) by *Agistemus terminalis* (Quayle). 1: Grasping of the egg by a predator on the ventral side of satsuma mandarin leaf. 2: Holding of egg stalk by palp (Pa) and attacking on its base by rostrum (Ro). 3: Gripping of egg stalk (St) by using claws (Cl), sensory organ (SO) and tactile setae (TS) of the palpi. 4: Needle-shaped stylet (Sty) extruded from the rostrum (Ro) ready to attack on the egg surface. 5: Formation of hole on the egg (Eg) surface due to the penetration of rostrum (Ro) followed by its withdrawn by extended palpi (Pa). 6: Hole on the egg was made by palpi (Pa) and rostrum (Ro) of the predator.



Figs: 7-12: SEM micrographs on the grasping and feeding of the adult of *Panonychus citri* (McGregor) by *Amblyseius sojaensis* Ehara. 7: Grasping of the adult red mite from its anterior portion by a predator on the ventral side of satsuma mandarin leaf. 8: Pressing on the prey body by the predator with palpi (Pa) in coordination with the holding by forelegs. 9: Hooking of several sharply pointed and bent setae (Se) of the palpi (Pa) into the cuticle (Cu) of the prey. 10: Attacking on the abdomen of the prey where the predator's forelegs hold and palpi (Pa) gripped the prey body. 11: Lacerated cuticle (Cu) on the prey body at the base of setae where the predator attacked by its chelicerae (Ch). 12: Extended corniculus (Co) with tube-like malae (Ma) between them under the pierced chelicerae (Ch) into the prey body.

bent towards the body of the prey and invaded the cuticle (Cu) by using force of the palpi (Pa) (Fig. 9).

The prey was gripped by the palpi (Pa) and forelegs. The palpi were bent to make way for the chelicerae and moved toward the cuticle (Fig. 10). The chelicerae (Ch) extended beyond the palpi to approach the tubercles on cuticle (Cu) of the prey for puncturing and tearing. The cuticle was lacerated (arrow), especially at the base of setae where the predator attacked by its chelicerae (Fig. 11). The chelicerae (Ch) pierce into the cuticle and the corniculus (Co) were opened to puncture the prey body. The tube-like malae (Ma) were present between these corniculus for the extraction of fluid and were directed to the cuticle (Fig. 12).

Discussion

The predatory mites are mostly fluid feeders and locate their prey by random contact or by chemical cues produced by the prey (Walter and Lindquist, 1989). We found that *Agistemus terminalis* and *Amblyseius sojaensis* firstly touched the prey with their palpi and legs. Searching of food in most cases occurred with the examination of objects by tapping them with the first pair of legs and palpi and the regular inspection appears suitable for preying (Lee, 1974). *Agistemus terminalis* uses palpi and forelegs while *Amblyseius sojaensis* used palpi. First and second pair of legs were used for selection and immobilizing of prey during the process of searching, grasping and attacking.

The palpi of the Prostigmata may be linear and the simple sensory appendages might be modified for the purpose of grasping and tearing, forming a thumb claw (Lee, 1974). The tibial claw has also been used for digging and attacking the cuticle of the host before the commencement of feeding (Usher and Bowring, 1984; Baker, 1991). We observed that *Agistemus terminalis* possessed two sharp and strong claws, which griped the egg stalk in coordination with the sensory organ. This method was utilized for capturing the egg and it may also suggest that sensory information were thereby provided. While *Amblyseius sojaensis* has thick setae, of which the apices were bent in hooked style on the palpotarsal segment and it may play a role for grasping and probably for sensing.

In *Pergamusus brevicornis*, the chelicera draws the prey towards the hypostome thereby impales it on the gnathotectal process and corniculi (Zukowski, 1964). This preying method contradicted with that in Rhodacaridea (Lee, 1974). *Agistemus terminalis* bends palpi probably for providing back-and-forth movement of the rostrum to get the egg closer and to invade into the eggshell. While *Amblyseius sojaensis* used palpi and forelegs to bring the prey near the mouthparts to grasp with palpi.

The cheliceral digits cut or tear the body of the prey, which rapidly immobilizes them, and the combined actions of these organs during back-and-forth movement of the chelicerae lacerate the internal organs (Wernz and Krantz, 1976). In contrast, *Agistemus terminalis* used palpi for back-and-forth movement of the rostrum, and the rostrum acted as a drilling organ to make hole into the eggshell. Simultaneously, stylets protruded from the rostral apex for the extraction of egg fluid. It seems that the protraction and retraction of the stylet along with the palpal movement may be the striking phenomenon in this mite. Whereas, *Amblyseius sojaensis* punctured the prey body by its corniculi and chelicerae. The tube-like malae sucked the fluid of the prey.

In conclusion, *Agistemus terminalis* used palpi, sensory organ, rostrum and claws for grasping and puncturing the prey, while a pair of needle-shaped stylet extrudes from the rostral apex for sucking of egg fluid. The process is accomplished with the movement of the palpi to break the eggshell. *Amblyseius sojaensis* possessed long and thick setae of the palpi for grasping the prey while corniculi, chelicerae acts as a breaking and piercing organs. Malae have a tube-like structure, which sucks the fluid of the prey.

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