

WAXY PARTICLES - THE 'OVERCOAT' ON ADULT WHITEFLIES

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Abstract

Whiteflies and whitefly-infested leaves often have a white or grayish appearance much of which is due to copious amounts of waxy particles produced by adults. Adult male and female whiteflies begin producing waxy particles immediately after emergence and spread these particles over all parts of their body, except for their eyes. The silverleaf whitefly and the greenhouse whitefly form near-circular particles about 1 micrometer (μm) in diameter. The giant whitefly forms waxy fragments 10-30 μm in length and 2-2.5 μm in width. In all whitefly species, the waxy particles are composed of a mixture of long-chain aldehydes and long-chain alcohols. The female giant whitefly also has two pair of wax plates on her posterior abdomen with which she produces waxy filaments and uses to form the spiral egg trails. The physical and chemical properties of the waxy materials produced by three species of whitefly pests are described, as well as the morphology of the wax plates.

Introduction

Adult whiteflies begin producing waxy strands from abdominal wax plates immediately after emergence. The waxy particles are formed when the adult whitefly rakes its hind tibia (legs) across the extruding waxy filaments, breaking them off (Byrne and Hadley, 1988). The adult whitefly periodically grooms itself, covering and recovering its body with the white waxy particles, except for the eyes (Figs. 1-3) The waxy particles stick to the velcro-like hairs on the body and wings, and to the hairs on the antennae. Copious amounts of waxy particles are dislodged from the insect, covering nymphs and surrounding leaf surfaces helping to give them a whitish-grayish appearance.

Results and Discussion

The waxy particles produced by the silverleaf whitefly, *Bemisia argentifolii*, the greenhouse whitefly, *Trialeurodes vaporariorum*, and the giant whitefly, *Aleurodicus dugesii* are extruded from specialized pores on wax glands (wax plates)

which cover a major portion of the abdomen (Figs. 4-6). A morphological description of all stages of *T. vaporariorum* and its waxy particles has been reported (Domenichini, 1981). There are two pair of wax plates on the female and four pair on the male of the silverleaf whitefly, *Bemisia argentifolii*, and the greenhouse whitefly, *Trialeurodes vaporariorum*. The giant whitefly, *Aleurodicus dugesii*, also has two pair of waxy particle-producing wax plates on the female, but has three pair on the male abdomen (Nelson et al., 1999). In addition, the female giant whitefly has two pair of wax plates on her posterior abdomen that produce waxy filaments which she deposits on the underside of the leaf to form circular trails, presumably to camouflage her eggs which are laid horizontally in the waxy trails. These posterior wax glands do not begin producing waxy filaments until the female is 48 hours-old and ready to lay her eggs. They are broken off as she periodically lowers her abdomen to the leaf surface and moves in a circular pattern.

Waxy particles can have a variety of shapes depending on the species. The waxy particles are initially formed as filaments which are extruded through many pores or microtrichia, covering the entire wax plate. The wax plates, which cover the majority of the abdominal surface (Figs. 7-9), are composed of microtrichia (Table 1). The shape of the microtrichia resembles a 'T' and they are the pore from which the waxy material is extruded (Table 2). The microtrichia of the silverleaf whitefly appear as parallel rows (Fig. 10), those of the greenhouse whiteflies as parallel sets of three rows each (Fig. 11) and those of the giant whitefly appear in vertical and horizontal rows (Fig.12). The silverleaf whitefly (Figs. 13, 16) and the greenhouse whitefly (Figs. 14, 17) break off the filaments to form near-circular particles about 1 μm in diameter which take the shape of a 'C', whereas the giant whitefly (Figs. 15, 18) forms elongated waxy fragments. Because the chemistry of the waxy particles is almost identical, differing only in the chain length of the aldehydes and alcohols, the final shape of the particle appears to be dependent upon the shape of the microtrichia. If the 3 'ribs' on the particles are evenly spaced, as on the giant whitefly, the particle remains relatively straight. If one of the 'rib's is positioned as a 'backbone', then the particle bends forming a 'C' as seen on both the silverleaf and greenhouse whiteflies.

The female giant whitefly also produces waxy filaments with her posterior abdominal wax plates (Fig. 19) which she uses to form the spiral egg trails. These wax plates do not begin producing waxy filaments until about two days postemergence. These wax plates have microtrichia in the shape of a triangle (Fig. 20) and contain 5.06 ± 0.49 microtrichia per μm^2 . The triangular-shaped microtrichia have a length of 0.49 ± 0.01 μm and a width of 0.42 ± 0.01 μm . The filaments produced by these microtrichia (Fig. 21) have been measured up to 620 μm in length on a female that was pinned on her back so she could not break off the

filaments. They are naturally broken off to form clusters of filaments on the leaf surface as the female periodically lowers her abdomen to the leaf surface as she moves in a circular pattern. Because the wax plates occur as a pair, two clusters of filaments are broken off each time she lowers her abdomen. This produces a chevron-like pattern within the waxy trail.

The chemical composition of the particles, as well as the lipids on the cuticular surface, have been characterized for a number of species of adult whiteflies: *Bemisia tabaci* and *B. argentifolii* (Buckner et al., 1994; Nelson et al., 1994); *Aleuroplatus coronata*, *Aleurothrixus floccosus*, *Aleurotithius timberlakei*, *Dialeurodes citri*, *Dialeurodes citrifolii*, and *Parabemisia myricae* (Nelson et al., 1997); *Aleyrodes singularis* (Nelson et al., 1998); and *Aleurodicus dugesii* (Nelson et al., 1999).

The lipids obtained from the waxy particles found on all adult whiteflies examined to date are composed of a mixture of long-chain aldehydes and long-chain alcohols: the major components have carbon chains of 30, 32 or 34 carbons depending on the species. The major components for these three species have carbon chains of 30 carbons for *A. dugesii*, 32 carbons for *T. vaporariorum*, and 34 carbons for both *B. argentifolii* and *B. tabaci*.

The lipids from the waxy filaments (the egg-trail material) produced by the posterior abdominal wax plates of *A. dugesii*, were largely wax esters, predominately containing 46 carbon atoms and consisting mainly of triacontanyl hexadecanoate (a 30 carbon alcohol esterified to a 16 carbon fatty acid) (Nelson et al., 1999).

Summary

The biological function of the waxy particles produced by both male and female adult whiteflies is unknown. However, there is speculation that wax may reduce desiccation and predation. The importance of this material is indicated by both the large area of the abdomen occupied by the wax plates, and the large amounts of waxy material produced. The fact that the lipids from the waxy particles are composed of only two compounds, and that one of them is an oxidizable long-chain aldehyde which could form a toxic product, is surprising. The function of the waxy filaments produced by the posterior abdominal wax plates of female *A. dugesii* appears to be that of camouflaging her eggs. The shape of the particles and the chemistry of lipids from particles of the sweetpotato whitefly, *B. tabaci*, have been reported to be identical to those of *B. argentifolii*.

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- Nelson, D. R., M. Guershon and D. Gerling. 1998. The surface wax composition of the exuviae and adults of *Aleyrodes singularis*. Comp. Biochem. Physiol. 119B, 655-665.
- Nelson, D. R., C. L. Fatland, J. S. Buckner and T. P. Freeman. 1999. External lipids of adults of the giant whitefly, *Aleurodicus dugesii*. Comp. Biochem. Physiol. 123B, 137-145.
- Table 1. The number of microtrichia per square micrometer of the abdominal wax plates and the size of the waxy particles produced.

Species	Microtrichia Number/ μm^2	Waxy Particles	
		length (μm)	width (μm)
<i>B. argentifolii</i>	0.49 \pm 0.03	5.00 \pm 0.17	0.81 \pm 0.01
<i>T. vaporariorum</i>	0.47 \pm 0.04	4.68 \pm 0.18	0.86 \pm 0.01
<i>A. dugesii</i>	0.43 \pm 0.02	11.14 \pm 0.56	1.28 \pm 0.04

μm = micrometer; n = number of measurements - for microtrichia of the 3 species n = 10, 6 and 18, respectively; for waxy particles n = 67, 65 and 66, respectively. Values are mean \pm standard deviation

Table 2. The size of the 'arms' of the microtrichia in the abdominal wax plates.

Species		Arm length (μm)
<i>B. argentifolii</i>	(n= 60)	0.71 ± 0.01
<i>T. vaporariorum</i>	(n= 60)	0.80 ± 0.01
<i>A. dugesii</i>	(n= 60)	1.05 ± 0.01

μm = micrometer; n = number of measurements

Values are mean \pm standard deviation



Figure 1. Head of silverleaf whitefly - only the eyes are not waxed.

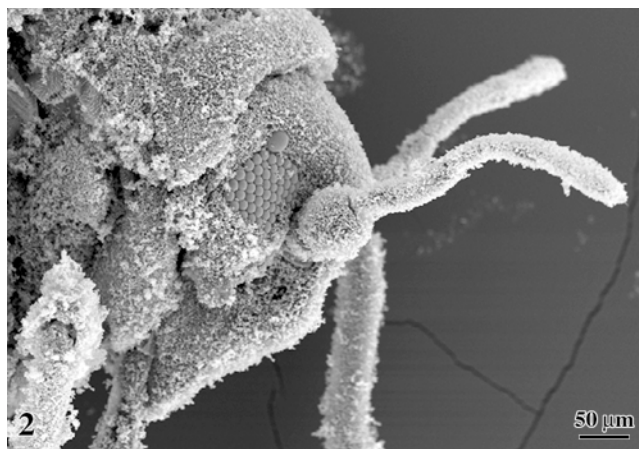


Figure 2. Head of greenhouse whitefly - only the eyes are not waxed.

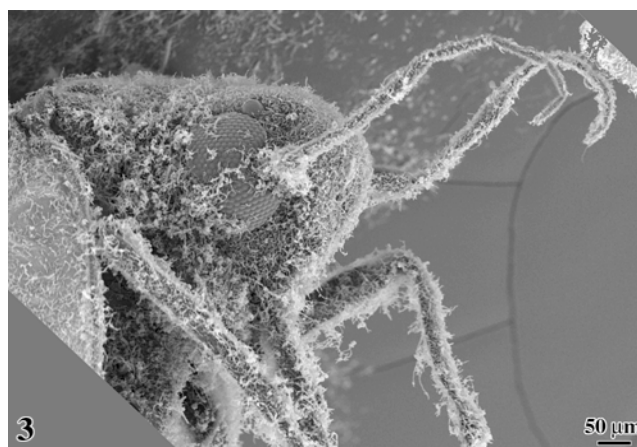


Figure 3. Head of giant whitefly - only the eyes are not waxed.

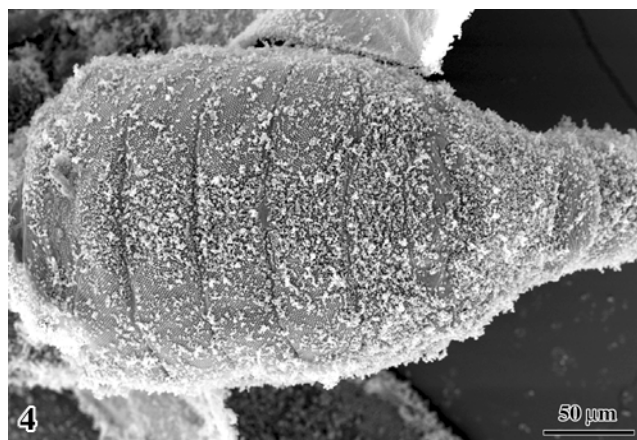


Figure 4. Waxed abdomen of the male silverleaf whitefly.

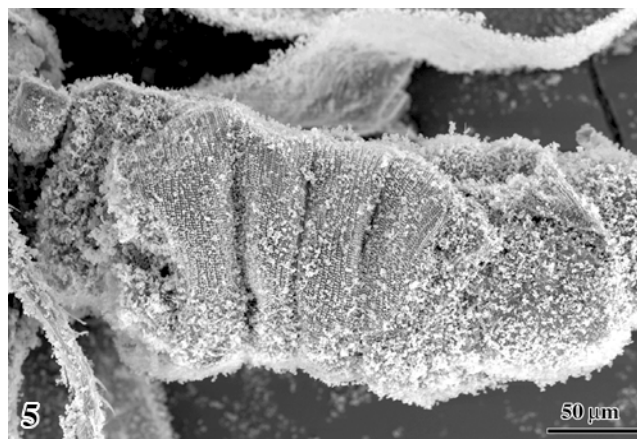


Figure 5. Waxed abdomen of the male greenhouse whitefly.

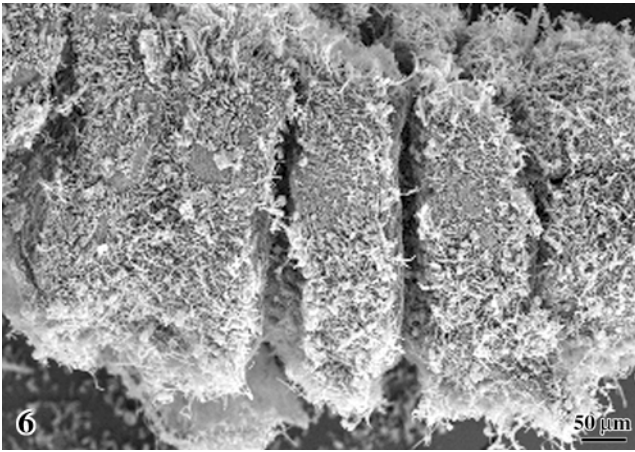


Figure 6. Waxed abdomen of the male giant whitefly.

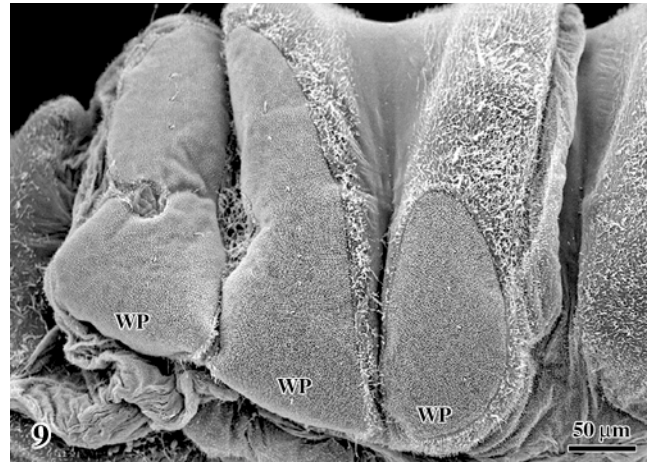


Figure 9. Wax removed from the abdomen of the male giant whitefly making visible 3 of the 6 wax plates (WP).

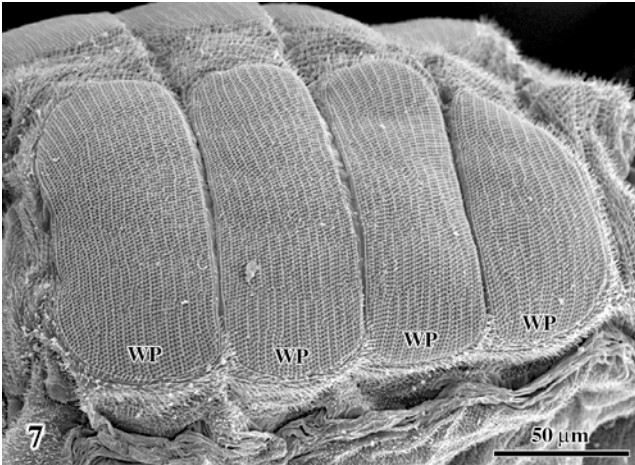


Figure 7. Wax removed from the abdomen of the male silverleaf whitefly making visible 4 of the 8 wax plates (WP).

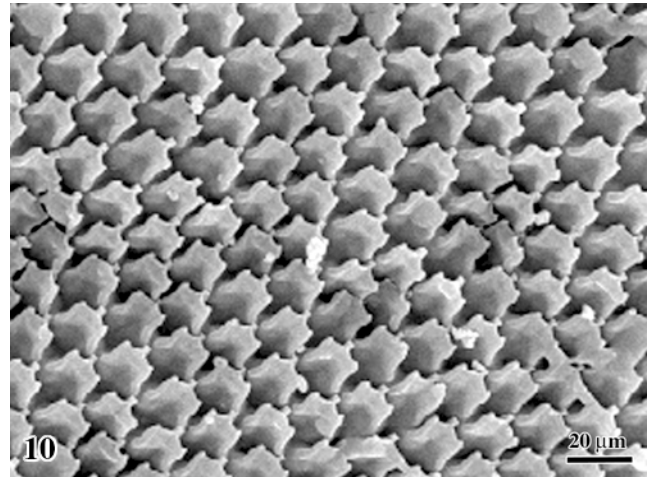


Figure 10. A portion of the wax plate (wax removed) showing details of the microtrichia of male silverleaf whitefly.

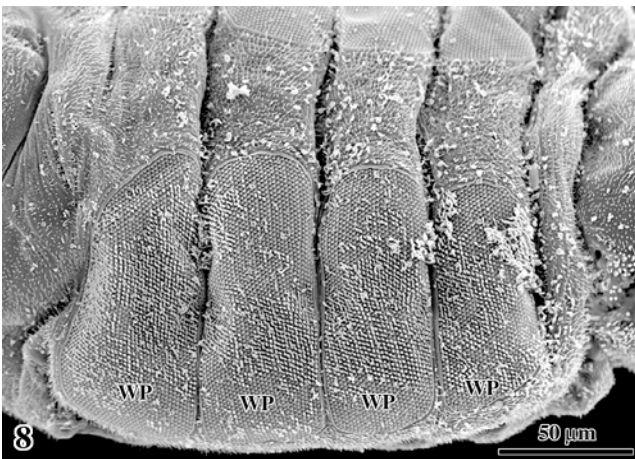


Figure 8. Wax removed from the abdomen of the male greenhouse whitefly making visible 4 of the 8 wax plates (WP).

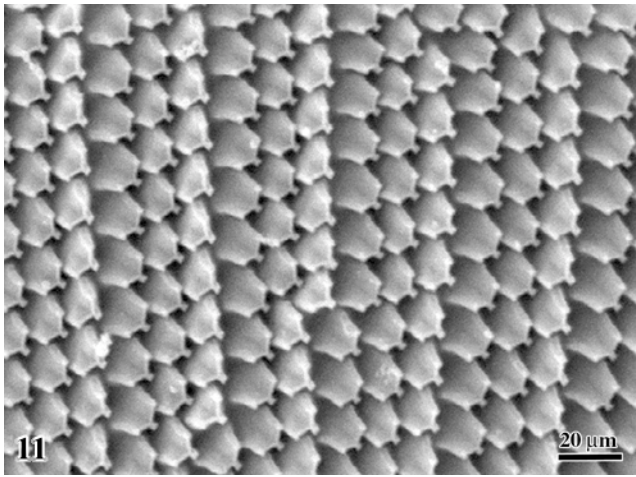


Figure 11. A portion of the wax plate (wax removed) showing details of the microtrichia of male greenhouse whitefly.

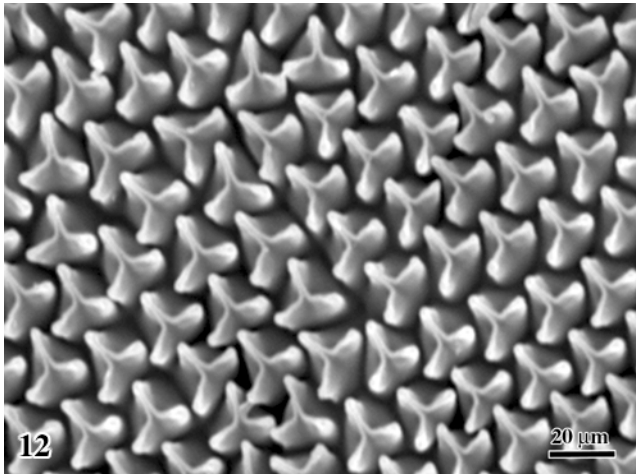


Figure 12. A portion of the wax plate (wax removed) showing details of the microtrichia of male giant whitefly.

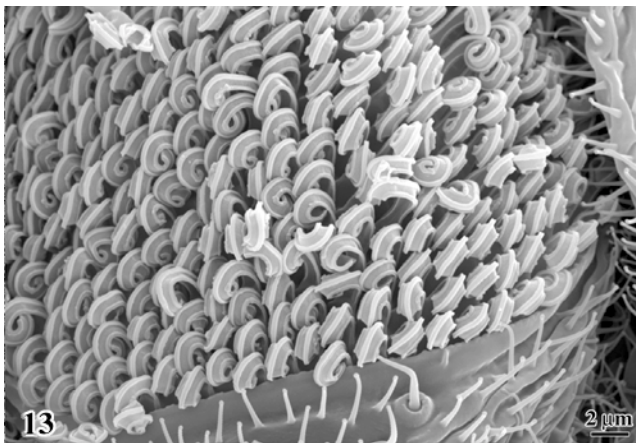


Figure 13. Waxy material extruded from the microtrichia of the male silverleaf whitefly.

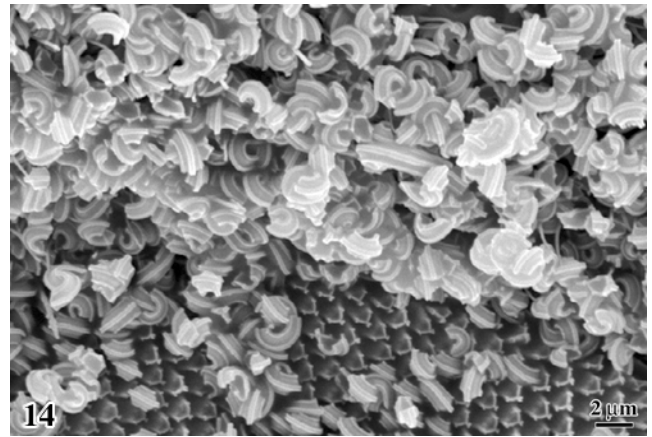


Figure 14. Waxy material extruded from the microtrichia of the male greenhouse whitefly.

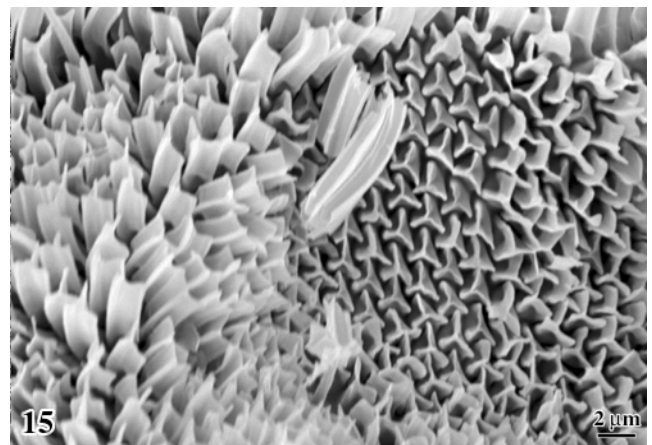


Figure 15. Waxy material extruded from the microtrichia of the male giant whitefly.

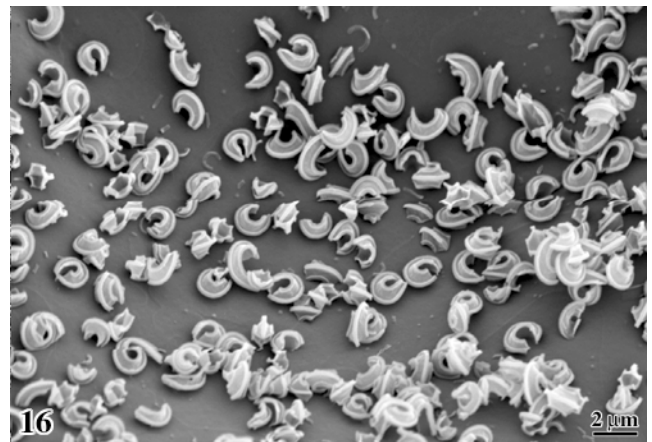


Figure 16. Particles of waxy material on the cuticular surface of the silverleaf whitefly.

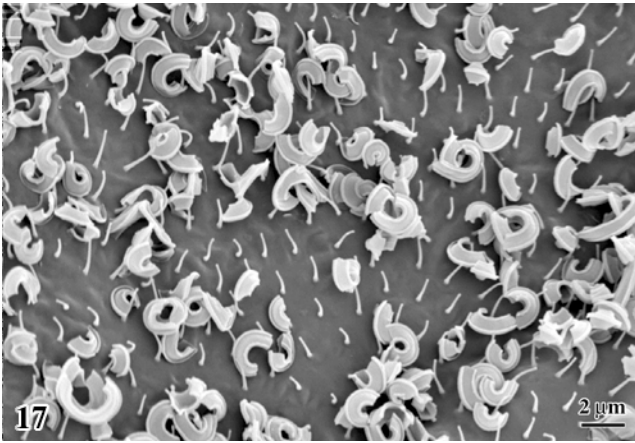


Figure 17. Particles of waxy material on the cuticular surface of the greenhouse whitefly.

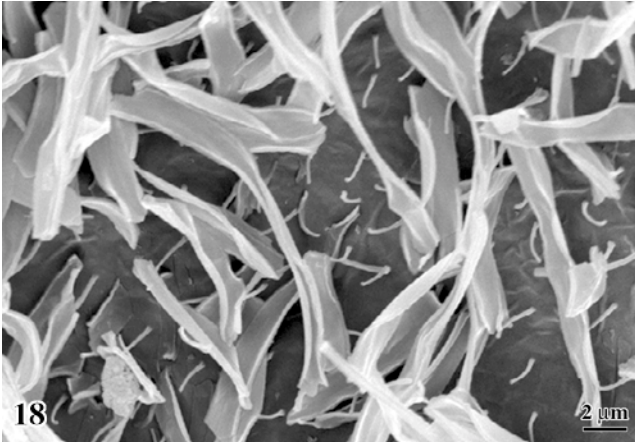


Figure 18. Particles of waxy material on the cuticular surface of the giant whitefly.

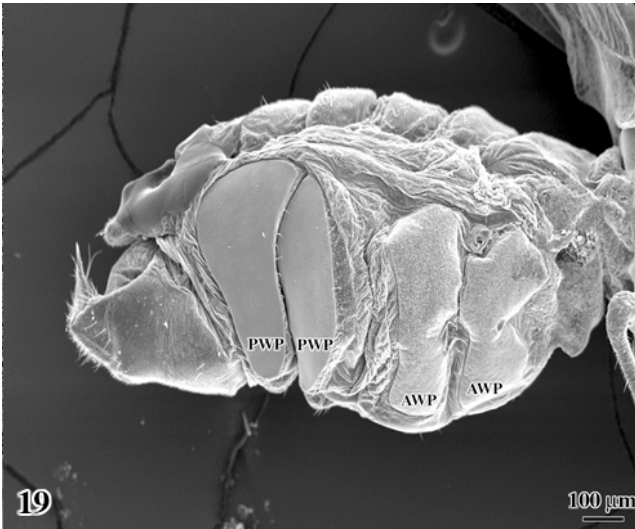


Figure 19. Wax removed from the abdomen of the female giant whitefly making visible 2 of the 4 anterior wax plates (AWP) and 2 of the 4 posterior wax plates (PWP).

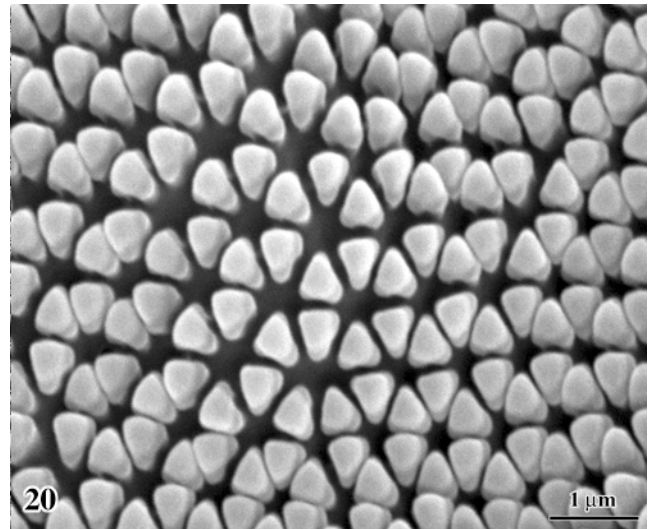


Figure 20. A portion of the posterior wax plate (wax removed) showing details of the microtrichia of the female giant whitefly.

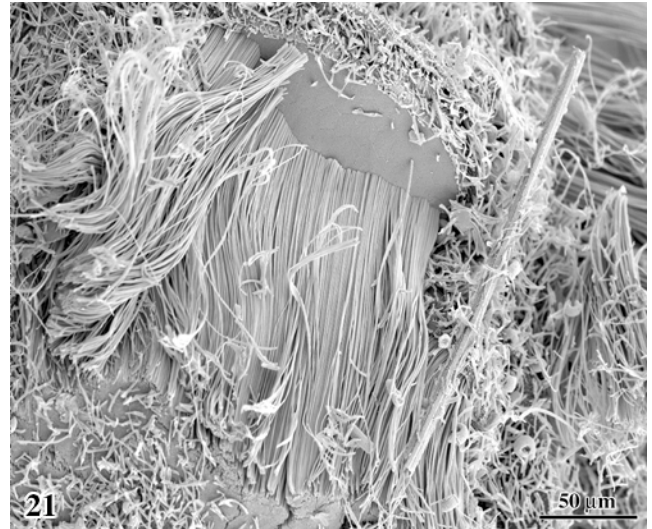


Figure 21. Waxy filaments extruded from the microtrichia of the posterior wax plate of the female giant whitefly.