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Morphometry of compound eyes of three *Bactrocera* (Diptera: Tephritidae) species

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Bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae), *Bactrocera dorsalis* (Hendel) and *Bactrocera tau* (Walker) are distributed widely in temperate, sub-tropical, and tropical regions of the world (Christenson & Foote 1960), and they infest a broad range of fruit and vegetable species (Hu et al. 2010). Compound eyes are important visual sensory organs with the capacity to distinguish colors and shapes (Briscoe & Chittka 2001), detect moving objects, and perceive the plane of polarized light (Horvath & Varju 2003). For a number of years various colors have been used as visual cues to trap fruit flies. For example, yellow traps were used for monitoring and controlling of *B. dorsalis* (Alyokhin et al. 2000). Moreover, Wu et al. (2007) demonstrated that *B. dorsalis* was attracted to green stimuli (spectra: 500-570 nm). Xue & Wu (2013) reported that the spectrum between 520-560 nm was more attractive to *B. cucurbitae* than either 480-500 nm or 560-600 nm. This study aimed to acquire additional relevant knowledge by morphometric investigations of differences between males and females and between the 3 species of various morphological features, including eye size, facet size, and numbers of ommatidia and ommatrichia.

Samples consisted of 20 individuals (10 males and 10 females) for each of the 3 *Bactrocera* species: *B. cucurbitae*, *B. tau* and *B. dorsalis*. Insects used in this study were obtained from laboratory colonies maintained at the Laboratory of Insect Ecology, South China Agricultural University, Guangzhou, China. Insects were reared in a cage (30 × 30 × 30 cm), fed artificial diet (yeast extract mixed with dextrose at a 1:3 ratio) and maintained at 28 ± 1.5 °C, 75-80% RH and 14:10 h L:D. Flies were killed by placing them in a freezer for 20 min, and then images were obtained using a dissection microscope (Zeiss, SteRED Discovery V12) connected to a computer. The heads of fruit flies were then dissected from the body by a sharp blade under the same dissection microscope. The specimens were fixed to aluminum stubs with conductive adhesive, and sputtered with gold for observation at 20 kV using a XL-30 ESEM scanning electron microscope.

The left compound eyes were observed and measured. Printed images were magnified, and optical microscope images were used to obtain measurements of dorso-ventral distance (eye width) and anterior-posterior distance (eye length) of the compound eyes, and the SEM images were used to obtain measurements of individual square ommatidium area per eye using a slide caliper (GB/T1214.1-1214.4, Shanghai Hengsheng Tools Co., Ltd., Shanghai, China). Additionally, we counted the numbers of ommatrichia and ommatidia using optical microscope images from the computer directly. Sexual dimorphism in the morphological traits was assessed in each species using the Mann-Whitney U-test ($P < 0.05$), while the general linear model (GLM) procedure and

a least significant difference (LSD) multiple comparison separation test were used to test for morphological differences among species. Statistical analyses were performed with SPSS 11.0.

The compound eyes of *B. cucurbitae*, *B. tau* and *B. dorsalis* were found to be ellipsoid in shape (Fig. 1). Each compound eye was comprised of a large number of ommatidia, which were packed closely together in a hexagonal and square arrays. The ommatidia at the center and posterior edge of the compound eyes were square, others were hexagonal. The ommatidia of the dorsal region were hexagonal and they were larger than the square ommatidia (Fig. 2). There were a several differences in morphological parameters between the sexes of the 3 species. The eyes of *B. dorsalis* females were wider than those of the males ($799.48 \pm 15.14 \mu\text{m}$ and $753.01 \pm 17.76 \mu\text{m}$, respectively), *B. cucurbitae* females had smaller individual square ommatidium area than males ($376.7 \pm 5.03 \mu\text{m}$ and $391.7 \pm 5.26 \mu\text{m}$, respectively), and *B. tau* females had more ommatidia than males ($3,904.12 \pm 42.1$ and $3,630.44 \pm 39.9$, respectively). There were no differences between the sexes in the other parameters measured.

There were some differences in eye morphology among the 3 species (Table 1). *Bactrocera dorsalis* had a smaller eye width and a smaller individual square ommatidium area than the other 2 species, and the largest number of ommatrichia. *Bactrocera tau* had the smallest number of ommatrichia, and the number in *B. cucurbitae* was intermediate. In all 3 species, the ommatrichia were either straight or curved hairs with blunt-tips. They were commonly located in basal sockets and sparsely distributed between the ommatidia.

In conclusion, we provided an extensive description of morphometric characters of the compound eyes of *B. cucurbita*, *B. dorsalis* and *B. tau*. The different morphometric characters among the 3 species of fruit flies may serve different functions. In arthropods, the size, shape, color, ommatidium number and surface texture of the compound eye influence many features of the visual field including its dimensions, acuity and sensitivity (Rutowski 2000). Differences in the morphology of the compound eye, which affect the visual field, should be expressed in differences in behavior, life style and habitat preferences that make different demands on the visual system (Horridge 1977; Warrant & McIntyre 1993; Land 1997). The findings of this study suggest that the 3 species of fruit flies may have the same spectral sensitivities of their photoreceptors. Since *B. cucurbita* and *B. dorsalis* were both attracted to colored paper with a spectrum between 520-560 nm (Wu et al. 2007; Xue & Wu 2013), presumably that the color preference of the *B. tau* also would be close to 520-560 nm. Our results can be helpful in exploring the relationship among the ultrastructural features of

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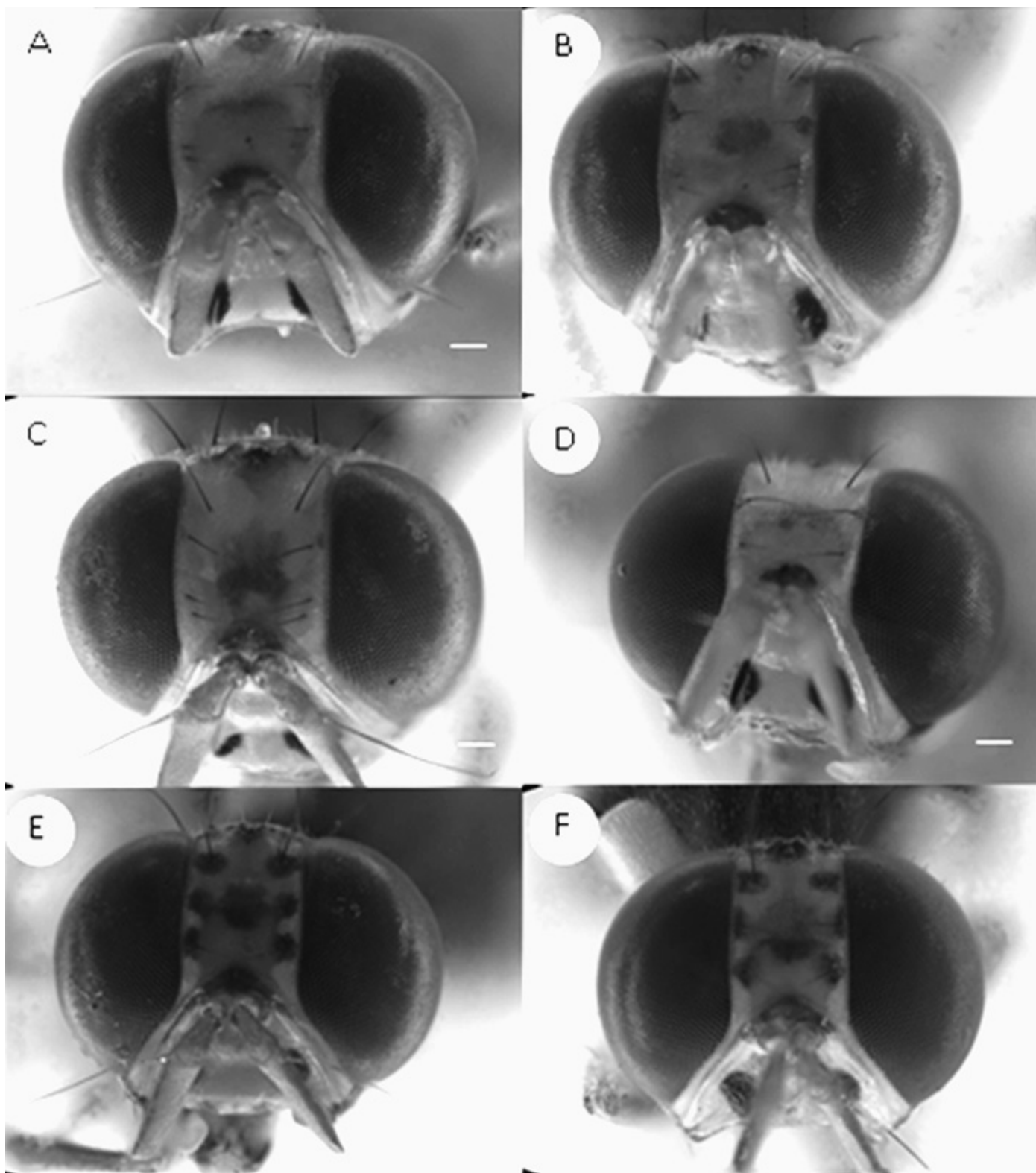


Fig. 1. Light micrographs of the compound eyes of the 3 *Bactrocera* species. Scale bar = 100 μ m. A: Female *B. cucurbitae* B: Male *B. cucurbitae* C: Female *B. tau* D: Male *B. tau* E: Female *B. dorsalis* F: Male *B. dorsalis*.

compound eyes, physiological mechanisms and phototaxis and other behaviors.

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Table 1. Morphological parameters of the compound eyes (mean \pm SE) of laboratory-reared adult *Bactrocera cucurbitae*, *Bactrocera tau* and *Bactrocera dorsalis* obtained by environmental scanning electron microscopy (ESEM) ($n = 20$).

Species	Number of ommatidia	Eye width (μm)	Eye length (μm)	Individual square ommatidium area (μm^2)	Number of ommatrichia
<i>B. cucurbitae</i>	3693.70 \pm 38.66 a	819.55 \pm 13.70 a	1283.92 \pm 12.39 a	384.21 \pm 3.93 a	137.10 \pm 2.60 b
<i>B. tau</i>	3767.25 \pm 42.22 a	822.05 \pm 11.13 a	1291.13 \pm 17.49 a	380.78 \pm 8.85 a	117.40 \pm 3.40 c
<i>B. dorsalis</i>	3751.80 \pm 37.84 a	776.25 \pm 12.55 b	1268.92 \pm 11.20 a	290.45 \pm 3.15 b	147.50 \pm 4.50 a
<i>F</i>	0.958	4.246	0.659	83.196	18.352
<i>P</i>	0.390	0.019	0.521	0.000	0.000

Means with same letters in a column are not significantly different (GLM, LSD, $P < 0.05$).

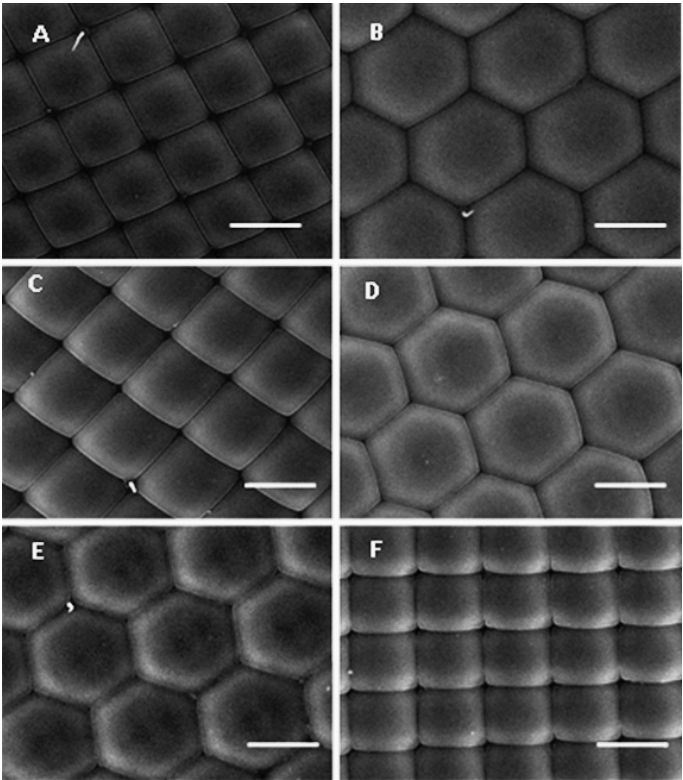


Fig. 2. SEM micrographs of the compound eye of 3 *Bactrocera* species showing the shapes of the ommatidia (square and hexagonal), central region (A, C, E) and dorsal region (B, D, F). Scale bar = 20 μm A, B: *B. cucurbitae* C, D: *B. tau* E, F: *B. dorsalis*.

Summary

We investigated the external morphology, eye size, facet size, and numbers of ommatidia and ommatrichia of the compound eyes of *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), *Bactrocera tau* (Walker) and *Bactrocera dorsalis* (Hendel) using light and scanning electron microscopy. There significant differences were found between females and males and between the 3 *Bactrocera* species. The results contribute to the further exploration of the relationship between the ultrastructural dimensions of the compound eye features and the visually-based behaviors of these 3 *Bactrocera* species.

Key Words: scanning electron microscopy; morphometric measurements; ultrastructure; fruit fly

Sumario

Investigamos la morfología externa, el tamaño de los ojos, el tamaño de las facetas y el número de ommatidia y ommatrichia de los ojos compuestos de *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), *Bactrocera tau* (Walker) y *Bactrocera dorsalis* (Hendel) usando microscopía de luz y electrónica de barrido (SEM). No se encontraron diferencias significativas entre las hembras y los machos de las 3 especies de *Bactrocera*. Los resultados contribuyen a la investigación adicional de las relaciones entre las dimensiones ultraestructurales de las características de los ojos compuestos y el comportamiento basado en lo visual de estas 3 especies *Bactrocera*.

Palabras Clave: microscopía electrónica de barrido; mediciones morfométricas; ultra estructura; mosca de la fruta

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