Aedeagal length and its variation of the peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae), which recently invaded Egypt

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Abstract

The aedeagal length, body size and number of pecten setae of the peach fruit fly, *Bactrocera zonata*, in Egypt were measured and compared with the sympatric species, *B. dorsalis* and *B. correcta* in Thailand. The body size of *B. zonata* was intermediate between *B. dorsalis* and *B. correcta*, with some overlap at each end. Aedeagal length of *B. zonata* was also intermediate between *B. dorsalis* and *B. correcta*, with no overlap. These results indicate that the 3 sympatric species can be distinguished by measurement of the aedeagal length. Because *B. zonata* recently invaded Egypt, it was expected that variability of morphological traits of this population would be smaller than what might be found in an indigenous *Bactrocera* population. However, coefficients of variation (CV) for body size, aedeagal length and number of pecten setae were similar to those for an indigenous population of *B. correcta*, indicating that the founder *B. zonata* population in Egypt had already acquired significant variation in these traits despite having passed through a presumed bottleneck situation. It was remarkable that the CV for aedeagal length was less than one half that for other traits, supporting the notion of stabilizing selection.

Key words: *Bactrocera zonata*, *Bactrocera dorsalis*, *Bactrocera correcta*, aedeagal length, stabilizing selection

INTRODUCTION

The *Bactrocera dorsalis* species complex in Southeast Asia is composed of 52 species (Drew and Hancock, 1994). Morphologically, some of the species in this complex are very close, and it has been difficult to distinguish among them (White and Elson-Harris, 1992), especially among 5 of the species that are of great importance economically. These are *B. philippinensis* and *B. occipitalis* in the Philippines, *B. carambolae* and *B. papayae* in the Malay Peninsular and Indonesia, and *B. dorsalis*. Taxonomic characters proposed by Drew and Hancock (1994) for distinguishing these species primarily involve the pattern of the black band on the abdomen and the costal marking of the wing. However, these characters are not reliable because they are polymorphic and a range of intermediate forms segregate within a species. Iwaiizumi et al. (1997) developed a simple method to distinguish 2 sets of sympatric species pairs, *B. occipitalis/B. philippinensis* and *B. carambolae/B. papayae*, based on aedeagal length. Although the aedeagi of *B. philippinensis* and *B. papayae* were significantly longer than those of *B. occipitalis* and *B. carambolae*, the flies they analyzed had been reared artificially and only a few specimens (*N*=5) were used for each species. Thus, Iwahashi (1999a) examined a large sample of fruit flies caught on Guimaras Island in the Philippines and found that males with aedeagal length (without distiphallus) of <2.81 mm were *B. occipitalis*, and those of >2.89 mm were *B. philippinensis*. Then Iwahashi (1999b) also examined another set of sympatric species, *B. papayae* and *B. carambolae*, in Singapore. Although aedeagal length did not segregate into 2 distinct groups when it was plotted against body size, males could nevertheless be divided into 2 distinct groups, larger and smaller groups. These results showed that sympatric species of the *B. dorsalis* complex can be distinguished based on measurements of aedeagal length.

Iwahashi (unpublished data) examined a total of 340 males, which were caught with methyl eugenol traps in Thailand, and found that all but 1 of the males belonged to 2 groups, shorter and longer aedeagal groups. The shorter group was mainly composed of *B. correcta*, whereas the longer group was composed of *B. dorsalis* and 2 males of another species. The 2 males resembled *B. zonata*, although they differed somewhat from typical *B. zonata* in possessing a transverse facial spot and
wider anal streak on the wing, in addition to a very small costal marking at the apex. Because the sample size was very small, he could not determine whether or not these males were aberrant \textit{B. zonata}. It was remarkable that the aedeagi of these 2 individuals were marginal lengths of the longer group. Although aedeagal length of \textit{B. zonata} is not indicated in the CABIKEY (White and Hancock, 1997), it shows that the aculeus length of \textit{B. zonata} is identical to that of \textit{B. correcta}. If so, \textit{B. zonata} should not belong to the longer group but to the shorter group because there is a strong correlation between the length of the aedeagus and that of the aculeus (Iwaizumi et al., 1997; White, 2000). Recently, \textit{B. zonata} invaded Egypt (Taher, 1998). It is likely that a small number of \textit{B. zonata} flies founded the Egypt and the population followed by an increase in population size once the colony became firmly established. If so, one might expect an increase in population size once the colony be-founded the Egypt and the population followed by

Degrees of variations for the 3 traits of \textit{B. zonata} in Egypt were also compared with those of the present study. The numbers of pecten setae on both sides of the abdomen were also recorded. The remainder of the body of the flies was kept individually and labeled in a plastic tube with 99% ethyl alcohol. Variability of the traits was expressed as the coefficient of variation (CV), which is the standard deviation divided by the mean. ANOVA and the Scheffé’s method were used for comparison of the measurements. The measured values (mm) of body size and aedeagal length were transformed into their natural logarithms. Thus, elevations and slopes of double logarithmic regressions were tested by ANCOVA and Tukey like test (Zar, 1999).

RESULTS AND DISCUSSION

Comparison of \textit{B. zonata} in Egypt with the CABIKEY \textit{B. zonata} and \textit{B. zonata}-like species in Thailand

Although more than 300 flies were collected in Egypt, all were identified as \textit{B. zonata}. Thus, 100 flies were randomly selected for analyses. Body size as measured by W1 ranged from 1.63 mm to 2.22 mm (Fig. 1). There was a strong correlation between W1 and W2 (W1=0.329W2±0.110, \(r=0.960, p<0.0001\)). Using this equation, the range of W2 of the CABIKEY \textit{B. zonata} (C-B.z., 5.2–6.1 mm) was transformed into W1, and a W1 range (1.82–2.12 mm) was obtained (Fig. 1, hollow bar). The filled bar in the figure is the range of the T-B.z. The figure indicates that ranges of the 2 bars fall into the range of E-B.z. Figure 2 shows the distribution of the aedeagal length of E-B.z. which ranged from 2.22 mm to 2.56 mm, while that of T-B.z. was from 2.33 mm to 2.34 mm (dark bar). The range of T-B.z. again fell into the range of E-B.z. The range of C-B.z. is not illustrated here because
data on aedeagal length were not available in the CABIKEY. These results indicate that the T-B.z. males are not aberrant in terms of body size and aedeagal length.

Comparison of B. zonata with B. dorsalis and B. correcta

Body size differed significantly among the 3 species (Fig. 3) (ANOVA, $F=144.069, p<0.0001$). The W1 of B. zonata (2.04±0.06 mm, mean±SD) was significantly larger than that of B. correcta (1.94±0.12 mm, $p<0.0001$), and significantly smaller than that of B. dorsalis (2.21±0.15 mm, $p<0.0001$) in Scheffé’s test. Using the regression of W1 on W2, the W2 ranges of the CABIKEY species were transformed into the W1 ranges, and are shown by black bars on the left side of the boxes. The black bars show that in the CABIKEY, species difference in maximal body size of B. zonata (2.12 mm) and that of B. correcta (2.08 mm) is only 0.04 mm, whereas, it was 0.23 mm in the present study (2.22 mm for B. zonata and 1.99 mm for B. correcta). In contrast with the prediction by the CABIKEY, where aedeagal length of B. zonata is similar to that of B. correcta, aedeagal length differed significantly among the 3 species (ANOVA, $F=1705.045, p<0.0001$). Aedeagal length of B. zonata (2.37±0.074 mm) was significantly shorter than that of B. dorsalis (2.72±0.111 mm, $p<0.0001$) and longer than that of B. correcta (2.06±0.076 mm, $p<0.0001$) in Scheffé’s test (Fig. 4). Thus, when aedeagal length was plotted against body size (W1), B. zonata was distributed between the 2 species, with no overlap with B. correcta and a few individuals overlapping into the distribution of B. dorsalis (Fig. 5). The log-log regression slopes did not differ among the species (ANCOVA, $F=0.081, p=0.922$), whereas the elevations differed significantly (ANCOVA, $F=614.22, p=0.0000$), indicating that B. zonata does not belong to the longer or the shorter aedeagal groups but represents an intermediate group. Thus we conclude that the 3 sympatric species can be distinguished based on aedeagal length. It is remarkable that all 3 slopes of the log-log regressions, ranging between 0.192 and 0.364, differed significantly not only from 0 but also from 1 (Table 1). Thus, larger males possess relatively a shorter aedeagus than smaller males. Such a weak influence of body size on aedeagal length can be explained by stabilizing selection (Eberhard et al., 1998).

Fig. 1. Distribution of body size (wing cell dm along with vein CuA1) of B. zonata in Egypt. Hollow and filled horizontal bars indicate the range of the CABIKEY B. zonata (White and Hancock, 1997) and B. zonata-like males in Thailand, respectively.

Fig. 2. Distribution of aedeagal length (without distiphallus) of B. zonata in Egypt. Filled horizontal bar indicates the range of B. zonata-like males in Thailand.

Fig. 3. Box plots of body size (wing cell dm along with vein CuA1) of the 3 species: B. dorsalis, B. zonata and B. correcta. Lines in the boxes, boxes and bars show 50 percentile, 25–75 percentile and 5–95 percentile of the sample, respectively. Bars at left side of the boxes are the range of the CABIKEY species (White and Hancock, 1997). Different letters show significant difference ($p<0.0001$ by Scheffé’s test).
During courtship, a *Bactrocera* male excretes droplets of pheromones from his anus, and transfers them onto the cubital cell hairs along vein A1 of the wing. The males release pheromone clouds by stridulating the cubital hairs of the wings with the setae on a pair of abdominal pecten (Kuba and Sokei, 1988). Thus, the pecten is essential for dispersal of the sex pheromone (Kuba and Sokei, 1988), and the number of pecten setae differs among species (Iwahashi, unpublished data). Although the number of pecten setae of *B. zonata* (39.9 ± 3.1) differed significantly from that of *B. dorsalis* (53.3 ± 6.9) (p<0.0001, Scheffé’s test), it did not differ from that of *B. correcta* (39.4 ± 3.7) (p=0.7268, Scheffé’s test), in spite of the significant difference in body size.

Given that a small number of *B. zonata* invaded Egypt and was followed by an increase in the population, one might have expected a lower level of variation of morphological traits than what one might expect to find in an indigenous *Bactrocera* population. It was remarkable that the 2 males that belong to the *B. correcta* group (dark circles) were completely isolated from the others (Fig. 5). It might be possible that these males belong to a different species from *B. correcta,* because there are many undescribed *Bactrocera* species in Thailand (I. M. White, personal communication). Thus they were excluded from the CVs calculations for traits of *B. correcta.* Although the CVs for the 3 traits (aedeagal length, body size and number of pecten setae) of *B. zonata* were smaller than those of *B. dorsalis,* they did not differ from those of *B. correcta* (Table 1). Thus we conclude that the *B. zonata* in Egypt had already accumulated enough variance in the 3 traits. The table also shows that the CVs for aedeagal lengths are less than one half of those for the other 2 traits in all 3 species. A similarly smaller CV for a genital trait than for a non-genital trait has also been interpreted to result from stabilizing selection (Eberhard et al., 1998).

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REFERENCES