

Expression of Body Colour Patterns In Three Castes of Four Asian Honeybees

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Abstract

Asian honeybees were collected during many years in several countries. Body colour pattern of the integument was investigated.

A. florea workers are of the yellow body colour type, which means, that yellow-orange bands are present on the abdomen. The queens are of the same type. The drones are black.

A. andreniformis workers have orange scutellum and narrow orange bands on the abdomen. Queens and drones are black.

A. dorsata workers are of the yellow type. The queens have brown bands on the abdomen, and the drones light brown patterns.

A. cerana, worker bees are of the yellow type, and queens and drones are brownish-black.

The gene responsible for body colour in *A. florea* is designed as *Fl*, in *A. andreniformis* as *An*, in *A. dorsata* as *Do*, and in *A. cerana* as *Ce*. Yellow *A. florea* queen produces black drones. Crossing yellow *A. florea* queen with black drones results in yellow type workers. Crossing brown *A. dorsata* queen with brown drones results in yellow type workers. Brownish-black *A. cerana* queen mated to brownish-black drones produces yellow type workers.

Expression of body colour in three castes of *A. florea* depends upon the sex (males black, females yellow) and in *A. andreniformis*, *A. dorsata* and *A. cerana* upon the sexuality (workers with yellow-orange bands, sexuals - queens and drones brown or brownish-black). Expression of body colour in the three castes of Asian honeybees may be considered as an adaptation to the environmental living conditions.

Introduction

Body colour is the most distinct character of any honeybee species or subspecies. The pattern of light (yellow, orange) and dark (black, brown) colour varies between species, within species as well as between the three casts (workers, queens and drones) of the same honey bee colony.

Earlier papers concerning heredity of honey bee body colour are reviewed by Woyke (1977). According to Roberts and Mackensen (1951), at least seven different loci of genes affect the colour pattern of the abdomen. Combinations of those genes result in continuous series of colour from the darkest to the lightest abdomen. Kulinčević (1966) investigating abdominal colour of drones from different races and their hybrids found continuous series from the lightest to the darkest. However, the distribution of the offspring from hybrid queens showed bi-modal modality. Ruttner (1988 p. 69, and 1992 p. 180) also recorded bi-modal distribution of body colour among his collection of honey bees. Earlier, Woyke (1977) explained the bi-modal distribution of body colour. There are two major body colour genes: Y responsible for the yellow colour and y^b responsible for black colour. They are modified by 6 modifiers. As a result two groups of body colour bees appear: a series of yellow variations, and of black variations. There is a peak of frequency within the yellow range, and other within the black range. Between them, a depression of frequency occurs.

The gross appearance of the body colour of European honey bees is similar in all three castes. Workers, queens and drones of Italian bees appear to be yellow, and of the Middle European, Carniolan and Caucasian bees - black.

However, in African bees (*Apis mellifera scutellata*), Kerr (1969) described a sex limited body colour: gene Ac (abdomen castanho) which causes, that all drones are black (brown), although workers and queens are yellow. It was not known whether this was caused by different ploidy of the sexes, (drones - haploids, and females - diploids) or by some other reasons. Woyke (1971) reared diploid African drones, and showed them to be also black. Woyke and Kerr (1989) showed, that diploid y^{ac}/y^{ac} drones are black while Y/y^{ac} are yellow. Thus, the different body colour expression in drones and workers or queens in African honey bees was not caused by different ploidy but by different sex.

General description of body colour of one or three castes of Asian honey bees are given by several authors (Koschevnikov 1900, Buttel-Reepen 1906, Maa 1953, Kshirsagar 1969, Morse and Laigo 1969, Okada 1986 and others). However, variation of body colour of *A. cerana* workers were described (Maa and Sao 1947, Saab 1990) and seasonal colour variations were found (Okada 1986, Tsuruta, Matsuka and Sasaki 1989) The body colour pattern of Asian honey bees is different in the three castes. The purpose of this investigation was to study the principles of heredity and expression of body colour in the three castes of Asian honey bees, and not to describe the whole range of colour variation.

Material and Methods

The Asian honey bees were collected during 20 years in several countries. *Apis florea*, bees were collected in India and Thailand. Some were observed in Sudan. One *A. florea* colony in India was dequeened, and consequently the worker bees constructed emergency queen cells. The colony was brought to Poland where 7 queens emerged (Woyke 1993). Together more than 25 queens were examined.

Drones produced by laying workers in two colonies in Thailand were also investigated (Woyke and Wongsiri 1992).

A. andreniformis worker bees were collected in Thailand in 1993. Drones were kindly supplied by Dr S. Wongsiri, Thailand. Queens were only seen, but not collected.

Apis dorsata bees were collected in India and Thailand. Some were observed in Sri Lanka. Only two *A. dorsata* queens collected in India were investigated.

Apis cerana bees were collected in India, Thailand, China (including gynandromorph) and in Japan. Bees of some colonies of *A. cerana* originating from Pakistan (Peshawar) were also kept and investigated in Germany and in Poland (Woyke 1973a, 1973b). Queens were also reared in India (Woyke 1975). During queen rearing, laying workers appeared, and drones produced by them were investigated. Diploid drones of *A. cerana* were reared by the method of Woyke (1969), in Poona, India (Woyke 1979 and 1980).

The bees were preserved in 75 % alcohol or 5 % formalin. However, great part of the investigations was conducted on fresh specimens. The study concerns the body colour pattern of the integument (exoskeleton). Colour pattern of thorax, scutellum and abdominal terga was investigated. Description concerns bees in natural position. Since antecedent terga cover subsequent ones the anterior margin of a tergum is not visible. Only total terga of *A. dorsata* drones were investigated.

To exclude the interference of hairs' colour, investigation were conducted on bees submerged in water or alcohol. Body segments are not numbered according to Snodgrass (1956), but to most other descriptions. The propodeum anterior to the petiole is not counted as abdominal segment I. Segment posterior to the petiole is counted as abdominal segment 1. Since the principles of body colour expression in three castes of Asian honeybees were studied, different shade of the light colour is designed as yellow, although it may be orange. The variation of dark body colour patterns in particular castes is also not considered.

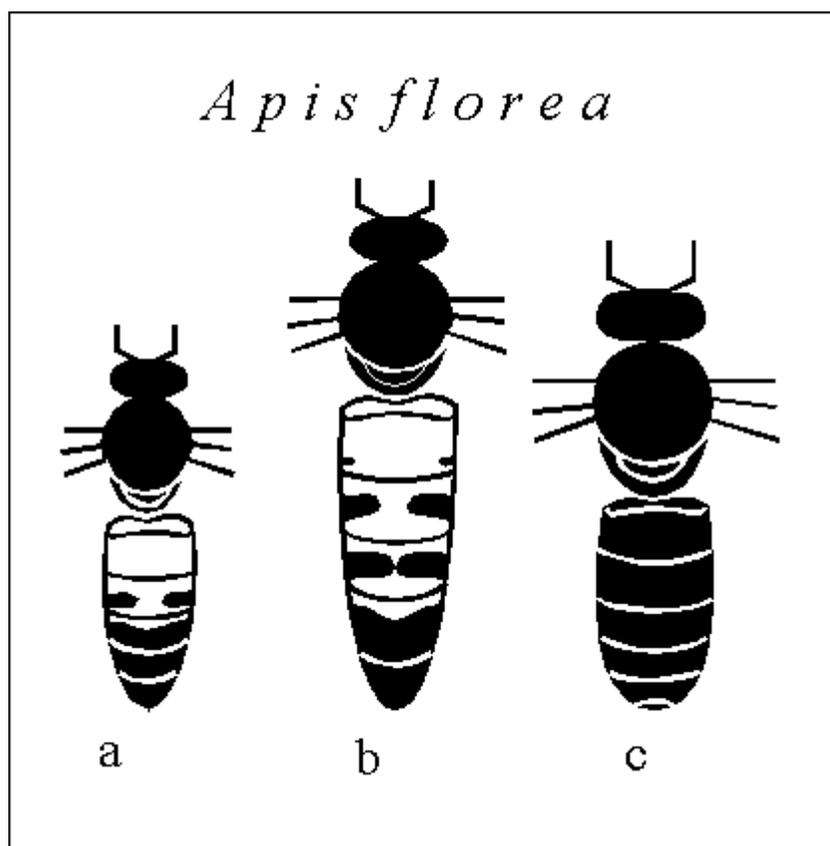


Figure 1. Body colour patterns in *A. florea*, a - worker, b - queen and c - drone. White colour in the figure is yellow-orange in the bees

Results

BODY COLOUR. *A. florea* workers are of the yellow type body colour, which means, that yellow bands are present on the abdomen (Fig. 1a). Virtually, they are yellow-orange. The thorax and the scutellum are black. The propodeum is also black. Two first abdominal segments are entirely yellow-orange. The other segments have black areas, or their posterior margins are black banded. The 2 - 3 last abdominal segments are black.

The queens are of the same type (Fig. 1b). However, light colour is found on larger area and on more segments of the abdomen. The lateral black areas are not on the posterior margins of the terga, but in their centrum. The 5th tergum is broadly black banded on the posterior margin. The apical segment is black. Consequently the queen is lighter than the workers.

The drone thorax, scutellum and abdomen are black (Fig. 1.c). The general appearance of a drone body colour is black. Drones produced by laying workers are of the same black colour.

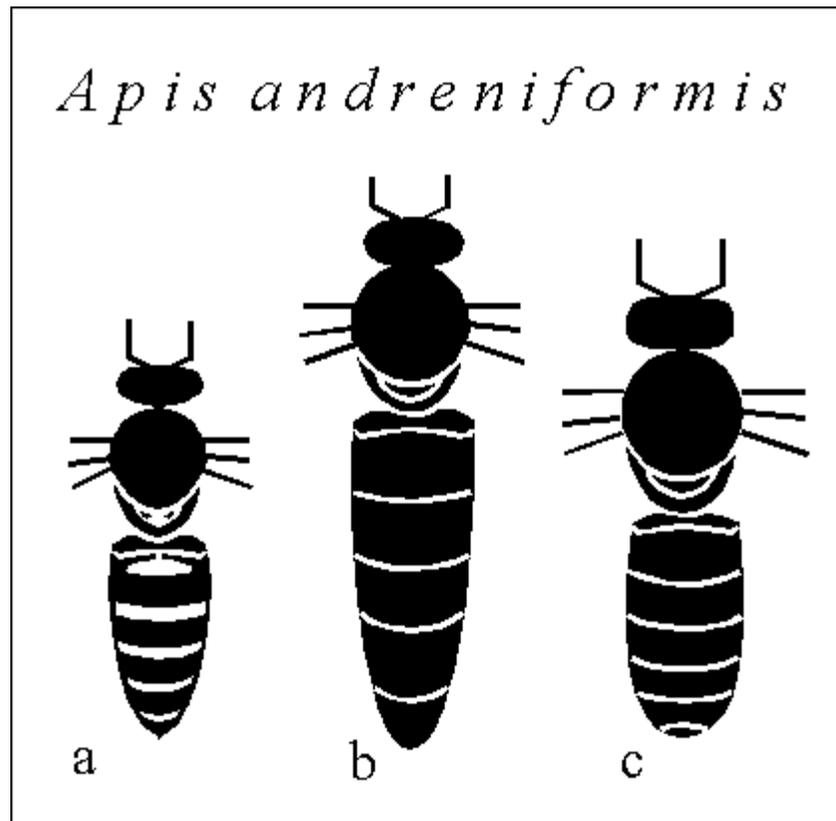


Figure 2. Body colour patterns in *A. andreniformis*, a - worker, b - queen and c - drone. White colour in the figure is yellow-orange in the bees

General appearance of *A. andreniformis* workers is dark (Fig. 2a). The light (yellow) areas are orange-brown. The thorax is black. The scutellum is light -orange or brown (which is different in *A. florea*). First abdominal segment is black. The second has a large dark orange elongated area. Narrow orange bands are present on the anterior margin of other segments. Queens are not in my collection. However, those which I have seen were black (Fig. 2b). Drones are also black (Fig. 2c).

A. dorsata workers are also of the yellow type (Fig. 3a). The thorax is black, and the scutellum is brown. The propodeum has some yellow area near the petiole. First abdominal terga are entirely or partly yellow-orange. Black small ovals are found on both sides near the posterior margin of one or more segments. The last 3 abdominal terga are brownish-black or black.

The queen's thorax is dark brown (Fig. 3b). The scutellum is light brown. The propodeum is dark brown with small light area near the petiole, like in workers. The first abdominal segments are light brown, with darker brown areas or bands. The dark brown areas on the second segment are smaller than on the next ones. Therefore, the two first abdominal segments look lighter

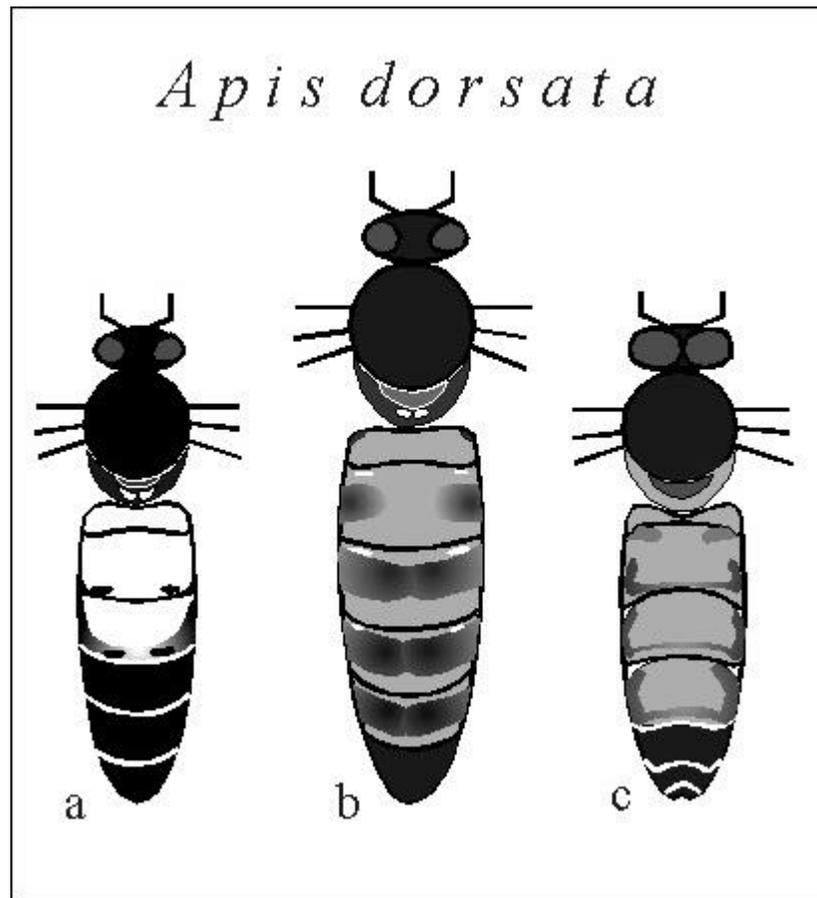


Figure 3. Body colour patterns in *A. dorsata*, a - worker, b - queen and c - drone. White colour in the figure is orange and gray is brown in the bees

than the others. Dark brown bands cover the subsequent ones, it seems that the brown bands are near the anterior margin of segments. Small yellow ovals are found on both sides of the front margins of those segments. The apical segment is dark brown.

The drone thorax is dark brown (Fig. 3c) and the scutellum is brown, being darker than in the queen. The propodeum is light brown, being lighter than in the queen. The abdominal terga are light brown with darker brown area. The margins of those areas are darker (Fig. 4). The last segments are dark brown.

A. cerana workers are also of the yellow type (Fig. 5a) However, some workers have very little light colour on the abdomen. The scutellum is

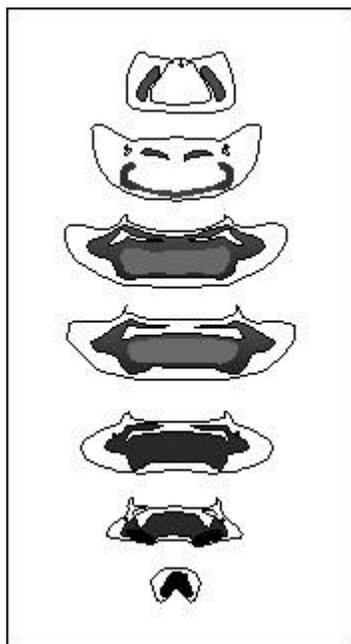


Figure 3. Colour patterns in terga of *A. dorsata* drones. White colour in the figure is yellow and gray is brown in the drones.

brownish yellow. The propodeum is black. The first abdominal segments are entirely orange, or they have black bands on their posterior margins. The last abdominal segments are black.

The queen has a black thorax (Fig. 5b). The scutellum is brownish-black, which differs from the light scutellum of the workers. The propodeum as well as all other abdominal terga are brownish-black. Living queens are looking entirely black. However, in queens preserved in alcohol, all abdominal segments are distinctly lighter than the thorax.

The drones have black thorax and the scutellum and all abdominal segments are brownish-black (Fig. 5c), similarly like in the queens. Drones produced by the yellow type workers were of the same colour as those produced by the queens. All diploid drones reared in India were coloured dark, similarly like the haploids.

The *A. cerana* gynandromorph (Fig. 6) had worker's head and drone's abdomen. Third left leg was of worker character and the right one of drone. The thorax was black and the scutellum brownish-black like in

drones. Abdominal worker body parts were of the yellow type like in workers and the drone ones were of the brownish-black type, like in drones.

HEREDITY. The gene responsible for body colour in *A. florea* is designed as *Fl*. Drones are black and queen and workers are of the yellow type. Yellow queen produces black drones. A cross of yellow queen with black drone results in yellow workers ($Fl/Fl \times Fl - Fl/Fl$). An F_1 queen which is the result of mating yellow P_1 mother with black P_1 father produces entirely black haploid drones. This means, that the F_1 queen is homozygous, concerning the body colour genes. If she was heterozygous, she would produce half black and half yellow haploid drones. Similarly, yellow laying workers produce only black drones. Accordingly, the yellow body colour of F_1 queens and workers is not the result of dominance of yellow colour over the black one. Thus, the expression of the action of the *Fl* body colour gene depends upon the sex - males are black and

females (queens and workers) are of the yellow type. However, the pattern of black and yellow colour is different in queens and workers. The queen has larger yellow areas than the workers. Thus, the expression of the patterns of body colour in the same sex depends upon their sexuality.

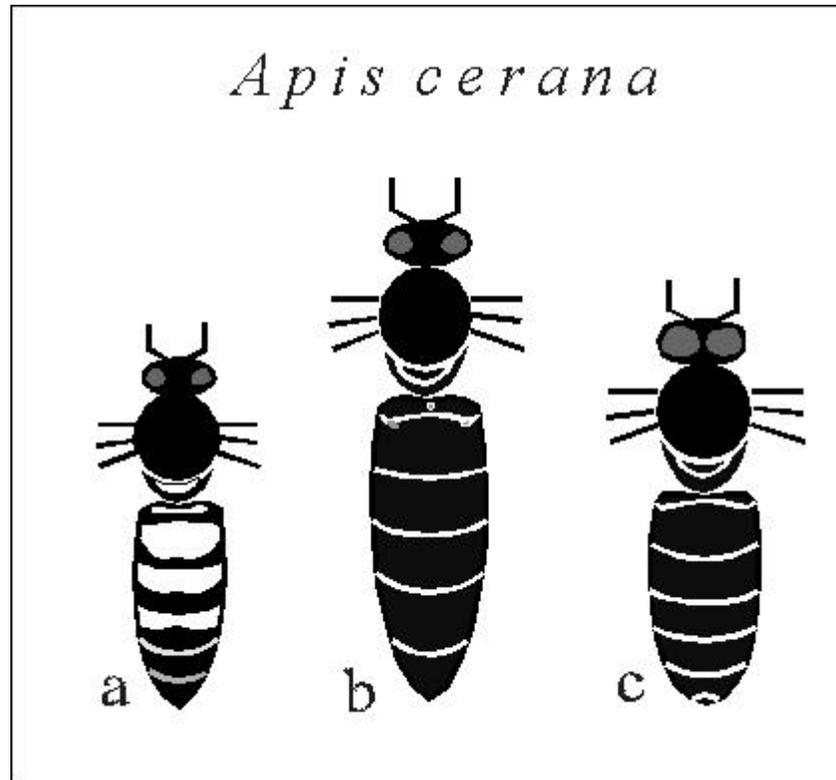


Figure 5. Body colour patterns in *A. cerana*, a - worker, b - queen and c - drone. White colour in the figure is orange and gray is brownish-black in the bees

The gene responsible for body colour pattern in *A. andreniformis* is designed as *An*. Workers are of the yellow type, although the darkest of all 4 species. Queens and drones are black. Crossing black queen with black drones results in yellow type workers. Thus the expression of body colour depends upon the sexuality.

The gene governing the body colour of *A. dorsata* is designed as *Do*. The workers are of the yellow type and queen and drones are of the brown type. Crossing brown queen with brown drone results in yellow worker type. Thus the expression of body colour in *A. dorsata* depends upon the sexuality of the castes. Workers are of the yellow type and the sexuals (queens and drones) are of the brown type. It can be expected, that yellow laying workers would produce brown drones.

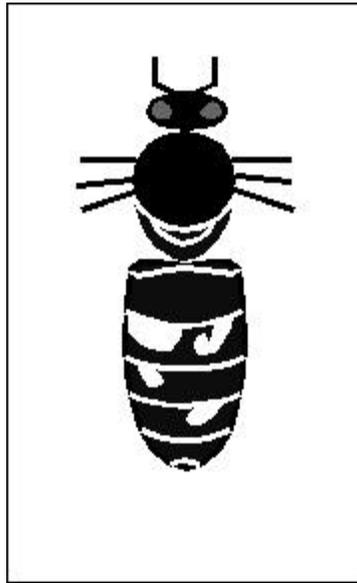


Figure 6. Gynandromorph of *A. cerana*..
White colour in the figure is orange and dark gray is brownish-black in the bees

The gene responsible for the expression of body colour type in *A. cerana* is designed as *Ce*. Workers are of the yellow types, and queens and drones of the brownish-black type. A cross between brownish-black queen and brownish-black drones results in yellow worker type. Yellow laying workers produce black drones. Diploid drones are of the brownish-black type like the haploids are, and not of the yellow type like the diploid workers are. Thus, the expression of the body colour type in *A. cerana* depends upon the sexuality of the castes. Workers are of the yellow type and the sexuals (queens and drones, independently haploid or diploid) are of the brownish-black type.

Dependence of the expression of body colour type upon the sexuality of the castes is described here for the first time for any honeybee species.

Discussion

The present investigation showed, that body colour differences in *A. florea* are linked to different sexes (females or males). However, in *A. andreniformis*, *A. cerana* and *A. dorsata* the body colour differences are linked to different sexualities (sexuals or infertile workers). This kind of body colour expression was not found in other *Apis* species. It is interesting to note, that the closest related species like *A. florea* and *A. andreniformis* or *A. cerana* and *A. mellifera* have very different mode of body colour expression. Thus the body colour expression should not be considered as a character in the evolution from more primitive to more specialised honey bee. However this character may be considered as an adaptation to the environmental living conditions. In the cavity living *A. cerana* bees, queens and drones are less visible and better protected when they are dark. In the open-air living *A. dorsata* species, queens and drones are less visible and better protected when they are of the brown colour of the comb and not much different from the colour of the workers. Contrary to *A. dorsata*, nests of *A. florea* are more hidden inside trees or bushes. Thus drones flying daily are less visible in the shade of trees and bushes when they are dark. *A. andreniformis* is living deep in the bushes, and the bees are better protected when they are dark.

Detailed patterns of body colour in four Asian honey bees are presented here for the first time.

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