August 22, 1991

JOURNAL OF THE KANSAS ENTOMOLOGICAL SOCIETY
64(2), 1991, pp. 193–196

Abnormal Sizes of Worker Honey Bees (*Apis mellifera* L.) Reared from Drone Comb (Hymenoptera, Apoidea)

HOWELL V. DALY[1] AND ROGER A. MORSE[2]

ABSTRACT: Worker honey bees were reared in the larger cells of drone comb in experimental colonies. Workers were unusually small when colonies were provided with only drone comb. Unusually large worker bees were reared when a colony was also provided with worker comb. The probable causes and implications of such potential size variation on morphometric identification of Africanized bees are discussed.

Worker honey bees in a normal, healthy colony exhibit a narrow range of body sizes that is typical of their subspecies. Factors promoting such uniformity in development include their shared maternal genetics, common nutrition as larvae, temperatures closely regulated by adult bees, and uniform dimensions of their brood cells. Experiments have demonstrated, however, that body sizes of bees can be influenced by a variety of environmental components (Alpatov, 1929). It is well known that the size of worker bees is influenced by the size of the brood cell in which they are reared; bees reared in larger cells such as those of drone comb are usually larger (Grout, 1937) and heavier (Nogueira and Goncalves, 1982) than bees reared in normal worker brood comb. Dwarf worker and drone bees also have been noted and probably result from underfeeding (Tucker and Nowogrodzki, 1990). In this paper, we report that abnormally small worker adults can be produced in drone cells if nurse bee behavior is disrupted by providing only drone comb in the hive. The implications of such potential size variation on morphometric identification of Africanized bees are discussed.

Methods and Materials

Workers reared in drone comb were taken from experimental hives in apiaries at the University of California at Davis and at Cornell University, Ithaca, New York. The hive at UC Davis was modified from those prepared for drone production. A small colony was placed in a single super with 8 frames of worker comb and 1 frame of drone comb drawn on an artificial wax drone foundation. Many of the worker combs had some pollen and honey, but none had brood. The queen was confined to the drone comb in a frame cage with queen-excluder sides. Among her progeny in the drone comb were both workers and drones.

In June, about 2 weeks after the frost-free date for the Ithaca, N.Y., area, 3 pounds of bees and a queen were shaken into a standard Langstroth super that contained 10 combs drawn from commercial drone foundation (Dadant and Sons, Hamilton, IL). The bees were fed a 50-50 sugar-water mixture, using a one-gallon feeder jar that rested on the tops of the frames. The combs had been drawn the previous year during a honey flow. The combs had been used for 1 season and most of the cells had been used for 2 to 4 brood cycles. There were no worker or transition cells in the comb except along the edge where the cells were joined to

[1] Department of Entomological Sciences, University of California, Berkeley, California 94720.
[2] Department of Entomology, Cornell University, Ithaca, New York 14858-0999.
Accepted for publication 15 September 1990.

Table 1. Means (M) and standard errors of means (SE) for 25 morphometric characters of two groups of European worker bees experimentally reared in drone cells (see text) compared in magnitude to the means of Africanized (A) and European (E) bees reported by Daly and Balling (1978).

Under columns A and E: < = M less than A or E, but not significantly so at alpha 0.05; <* = M significantly less than A or E at alpha 0.05, etc.

	Cornell bees				UC Davis bees			
Character	M	SE	A	E	M	SE	A	E
Forewing:								
Length	8.29	0.082	<*	<*	9.63	0.051	>*	>*
Width	2.84	0.037	<	<*	3.18	0.022	>*	>
Angle 29	33.6	0.70	>	>*	31.5	0.67	=	>
Angle 30	99.2	1.70	<*	<*	105.0	2.39	<	<
Angle 31	99.3	0.97	<	<	95.8	0.63	<*	<*
Angle 32	18.8	1.30	<	<	22.0	0.42	>*	>
Angle 33	92.9	1.07	<	<	92.7	0.82	<	<
Angle 34	54.4	1.21	>	>	54.3	0.92	>	>
Angle 35	22.9	0.75	<	>	24.5	0.48	>	>
Angle 36	62.8	0.87	>	>	65.4	0.72	>*	>*
Angle 38	91.6	0.94	>	<	89.5	0.97	<	<
Angle 39	44.4	1.44	>	>	45.0	0.70	>*	>
Cubital "b"	0.254	0.0100	>	>	0.232	0.0050	>	<
Cubital "a"	0.500	0.0158	<	<	0.588	0.0102	>*	>
Hind wing:								
Length	3.94	0.047	<*	<*	4.56	0.023	>*	>*
Width	1.58	0.026	<	<*	1.83	0.014	>*	>*
Hamuli	20.8	0.80	<	<	19.6	0.45	<	<
Hind leg:								
Femur length	2.39	0.033	<*	<*	2.75	0.014	>*	>*
Tibia length	2.93	0.042	<*	<*	3.35	0.015	>*	>*
Basitarsus length	1.78	0.030	<*	<*	2.10	0.015	>*	>*
Basitarsus width	1.03	0.018	<*	<*	1.19	0.014	>*	>
Sternum 3:								
Length	2.37	0.048	<*	<*	2.83	0.024	>*	>*
Wax mirror length	1.24	0.029	<	<*	1.42	0.019	>*	>
Wax mirror width	2.08	0.044	<	<*	2.40	0.030	>*	>
Between mirrors	0.216	0.0160	<*	<*	0.344	0.0124	>	>*

the wooden frame. The cells had a vertical orientation, i.e., the sides of the cells were vertical and the tops were peaked. There were 13.7 cells per 10 cm (7.3 mm in width). Worker cells vary but measurements of several commercial foundations and natural comb have shown widths of 5.05 to 5.64 mm (Erickson et al., 1990) for European honey bees.

The bees made no effort to tear down or rebuild the drone cells and for several weeks the queen laid eggs in a normal, compact brood pattern. The result was that about half of the cells contained what appeared to be normal drones (no samples of drones were taken) and the rest of the brood resulted in the undersized worker bees described here. No normal size worker bees were produced. The test colonies were replicated 3 times. The workers measured here were captured and pinned when they were about 1 week old.

A sample of 10 bees was taken from each colony. Following the procedure of Daly and Balling (1978), a fore wing, hind wing, hind leg, and third abdominal sternum of each bee was placed on a microscope slide. Fourteen length measurements, 10 venation angles, and the number of hamuli were recorded for each bee.

The means of the 25 characters for each of the two colonies were compared statistically with samples of Africanized honey bees ($N = 101$ samples, usually of 10 bees each) and European honey bees ($N = 297$ samples, usually of 10 bees each) as reported by Daly and Balling (1978). Statistical procedures followed Sokal and Rohlf (1981) and, for certain procedures, the statistical package BIOM by F. J. Rohlf was used: tests of equality of the 4 means for each character (Table 1) used the Games and Howell method after variances for some characters were found heterogeneous.

Results

In comparison with mean values of European worker bees measured by Daly and Balling (1978), workers reared from drone comb in the UC Davis colony are absolutely larger in 13 of 14 mean lengths and significantly so in 8 of the lengths (Table 1). Angles 31 and 36 located in the posterior distal area of the fore wing are significantly smaller and larger, respectively, than normal, but both angles are otherwise characteristic of European bees. When subjected to the morphometric identification procedure of Daly and Balling (1978) and based on the sample means, these large bees receive a discriminant score of -2.629 and are correctly identified as European at a probability of 1.00.

In contrast, the workers reared in the Cornell colony are absolutely smaller in 13 of 14 mean lengths when compared to the means of European bees and significantly so in 12 lengths. The Cornell bees are even smaller in these lengths than the mean lengths reported for Africanized bees, being absolutely smaller in 13 of 14 lengths and significantly so in 8 lengths (Table 1). Angles 29 and 30, within the third submarginal cell, are significantly larger and smaller, respectively, than normal European bees. The sizes of these angles are more similar to those characteristic of Africanized bees than of European bees. When subjected to the morphometric identification procedure, these small bees receive a discriminant score of 4.84 and are misidentified as Africanized at a probability of 1.00.

Discussion

We have shown that under different circumstances abnormally small and abnormally large worker honey bees can be reared from the large cells of drone combs. When other environmental factors are near normal, workers reared from larger cells are usually larger, as demonstrated in the UC Davis hive and elsewhere (Grout, 1937). In the Cornell hives, we speculate that the absence of worker combs caused the nurse bees to behave abnormally, leading to the partial starvation of the worker brood.

The small Cornell bees provide an opportunity to test the morphometric procedure of Daly and Balling (1978) to identify Africanized bees. Africanized bees are smaller than European bees in 13 of the 14 lengths used in the procedure. Daly (1975) recognized that unusual environmental factors might act on developing European workers to reduce body size and increase the chance of misidentifying them as Africanized. With only 2 choices for identification in the procedure,

Africanized or European, the morphometric procedure forces abnormally small European bees to be misidentified.

Tests of the method on abnormally small European worker bees have been made elsewhere and correct identifications have been obtained except for extremely small bees (Rinderer et al., 1986; Herbert et al., 1988). Conversely, Africanized worker bees reared by European nurse bees in the larger cells of European worker brood combs resulted in larger Africanized bees, but they were correctly identified by the morphometric method (Rinderer et al., 1986).

The small Cornell bees are misidentified as Africanized because 13 of 14 mean lengths, 4 of 10 mean angles, and the mean count of hamuli are closer to those of Africanized bees. The lengths make an especially strong contribution to the discriminant score because they are so much smaller than those of Africanized bees. The remaining 6 mean angles and mean cubital "b" length are closer to those of European bees, but their contribution to the score is insufficient to outweigh the abnormal measurements.

In conclusion, we offer a new experimental technique to produce unusually small worker bees. Although our experimental circumstances are unlikely in nature, the small bees that result could be misidentified by the morphometric method as Africanized bees. To avoid this potential error, we concur with Daly (1987) that a combination of independent sources of information be used in critical identifications.

Acknowledgments

We thank Jerry Marston, University of California at Davis, and Jan Nowakowski, Cornell University, for providing the specimens used in this study.

Literature Cited

Alpatov, W. W. 1929. Biometrical studies on variation and races of the honey bee (*Apis mellifera* L.). Quart. Rev. Biol. 4:1–58.

Daly, H. V. 1975. Identification of Africanized bees by multivariate morphometrics. Proc. 25th Int. Apic. Congr., Grenoble, France, pp. 356–358. Apimondia, Bucharest.

Daly, H. V. 1987. Overview of the identification of Africanized honey bees. *In* R. Page, G. Needham, and M. Delfinado-Baker (eds.), Proc. Internat. Conf. Africanized Honey Bees and Bee Mites, Columbus, Ohio, pp. 245–249. Ellis Horwood Publishing Co., Chichester, England.

Daly, H. V., and S. S. Balling. 1978. Identification of Africanized honey bees in the Western Hemisphere by discriminant analysis. J. Kansas Entomol. Soc. 51:857–869.

Erickson, E. H., D. A. Lusby, G. D. Hoffman, and E. W. Lusby. 1990. On the size of cells. Gleanings in Bee Culture 118:173–174.

Grout, Roy A. 1937. The influence of size of brood cell upon the size and variability of the honeybee (*Apis mellifera* L.). Iowa State College Agr. Expt. Sta. Res. Bull. 218.

Herbert, E. W., H. A. Sylvester, J. D. Vandenberg, and H. Shimanuke. 1988 Influence of nutritional stress and the age of adults on the morphometrics of honey bees (*Apis mellifera* L.). Apidologie 19:221–230.

Nogueira, R. H. F., and L. S. Goncalves. 1982. Study of gland size and type in *Apis mellifera* workers emerged from drone cells. Rev. Brasil. Genet. 5:51–59.

Rinderer, T. E., H. A. Sylvester, A. M. Collins, and D. Pesante. 1986. Identification of Africanized and European honey bees: effects of nurse-bee genotype and comb size. Bull. Entomol. Soc. Amer. 32:150–152.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, 2nd ed. W. H. Freeman and Company, San Francisco. 859 pp.

Tucker, K. W., and R. Nowogrodzki. 1990. Abnormalities and non-infectious diseases. *In* R. A. Morse and R. Nowogrodzki (eds.), Honey Bee Pests, Predators and Diseases, 2nd ed. Cornell University Press, Ithaca. 432 pp.