

COMPARATIVE BIOMETRICAL INVESTIGATION ON DIPLOID DRONES OF THE HONEYBEE

II. THE THORAX *

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Summary

A total of 10 758 measurements were made on the thorax and its appendages of 269 haploid and 295 diploid drones, 109 queens, and 248 workers. All individuals originated from 12 queens of *Apis mellifera ligustica*, *A. m. adansonii*, their backcrosses and some hybrids.

The structures measured were mostly larger in diploid than in haploid drones. The number of bristles on the forewing and the number of hooks on the hindwing were lower in diploids, and the cubital index was similar in the two types of drone. The relationships for the same characters in queens and workers were different; diploid drone characters were variously super-male, male or female, or caste characters.

Introduction

Preliminary reports (Woyke, 1971a, 1971b) and Part 1 of this study (Woyke, 1977) have already been published.

Materials and Methods

Using the same individual bees as in Part 1, 10 758 measurements of the thorax and its appendages were made. Altogether 295 diploid drones, 269 haploid drones, 109 queens and 248 workers were investigated. They originated from 12 queens: *Apis mellifera adansonii*, *A. m. ligustica*, backcross of Italian queens to drones from F₁ hybrid queens of the two races, and some hybrids. Usually 25 haploid and 25 diploid drones from each queen were investigated (Woyke, 1977, Table 1), but due to damage some characters were measured on slightly fewer individuals.

Exact locations from which the measurements were taken are shown in Fig. 1. The length of the thorax measured was the actual length, not the total length.

The bristles covering the forewings were counted using a grid (8 × 5 squares) in the × 10 eyepiece of a binocular microscope. Using the × 5 objective, the wing was placed so that the grid occupied the larger area shown in Fig. 1, and the bristles covering the upper surface were counted using the × 10 objective, in the smaller area in the centrum of the discoidal cell, which measured 0.760 mm × 0.457 mm (0.361 mm²). In all subsequent investigations the focus of the microscope was adjusted so that the area viewed measured exactly 0.8 mm × 0.5 mm (0.40 mm²).

The methods of statistical analysis were the same as in Part 1.

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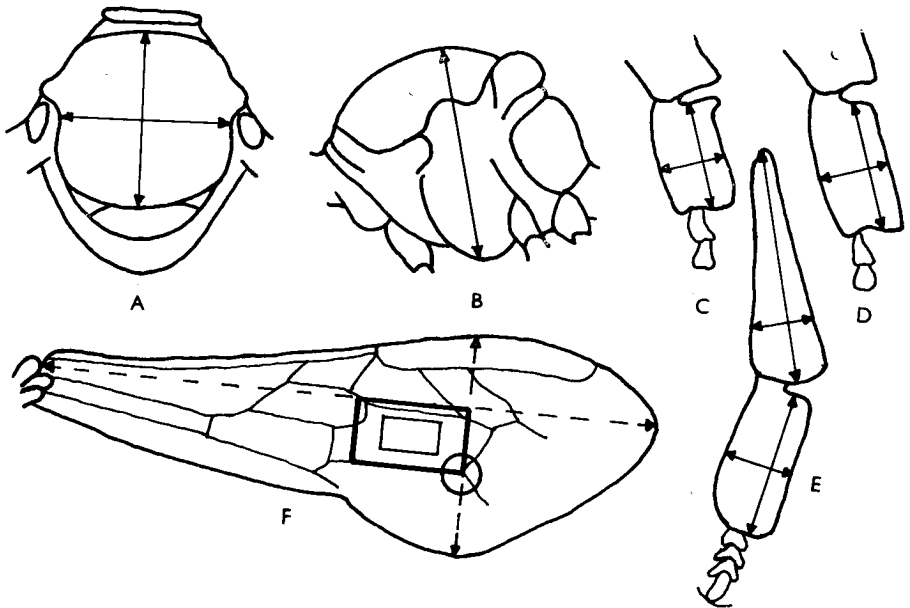


FIG. 1. Identification of characters measured.

Length and width of thorax (scutum) shown in A, and thickness of thorax in B. Length and width of hind basitarsus of worker shown in C, and of queen in D. Length and width of hind tibia and basitarsus of drone shown in E. Length and width of forewing, and rectangle in which bristles covering discoidal cell were counted (see text), shown in F.

Results

Size of thorax

Tables 1, 2 and 3 show that the thorax of the queen was significantly longer, wider and thicker than that of the worker. The drone thorax (both haploid and diploid) was much larger than those of the females. Diploid drones of pure races, and of some crosses, had a thorax very highly significantly larger than the haploid. In two or three crosses no significant differences were found between mean sizes of haploid and diploid drone thoraces; however, diploid drone thoraces were never found to be significantly smaller than those of haploid drones. The overall means for the three dimensions of the thorax were very highly significantly greater in diploid than in haploid drones. Thus the size of the thorax of diploid drones showed a super-male character.

Forewing

The forewings were all longer in queens than in workers (Table 4) and wider (Table 5) in all but 3 samples. The means for both length and width of forewing were greater in queens than in workers. Wing size of both haploid and diploid drones was greater than that of the females. Diploid drones of pure races had significantly or very highly significantly longer and wider wings than genetically similar haploid drones. However, the mean wing length of one backcross line (167) and width of one hybrid line (439) were significantly lower in diploid than in haploid drones. Overall length and width of forewing were very highly significantly greater in diploid than in haploid drones. Thus forewing dimensions in diploid drones showed mostly a super-male character.

The index of the forewing was mostly higher in queens than in workers (Table 6), but much lower in both types of drone. In 2 samples of diploid drones the cubital index

was significantly higher than in haploid drones, but in two further samples it was significantly lower. No significant differences were found in any other samples, or between the overall means, for the two types of drone. So the cubital index of diploid drones showed a typical male character.

The number of bristles covering the forewing (Fig. 2) has not previously been used to characterize bees. The wings of the queen have twice as many bristles as those of the worker (Table 7). Thus this character could be used for determining the extent to which an individual is queen-like or worker-like. As the number of wing bristles also varied greatly between bees of different races, this character might also be useful in their identification. The wings of both types of drone had half as many bristles as worker wings. Although the number of bristles on diploid drone wings was highly significantly lower than that on haploid drone wings, this also indicated a super-male character.

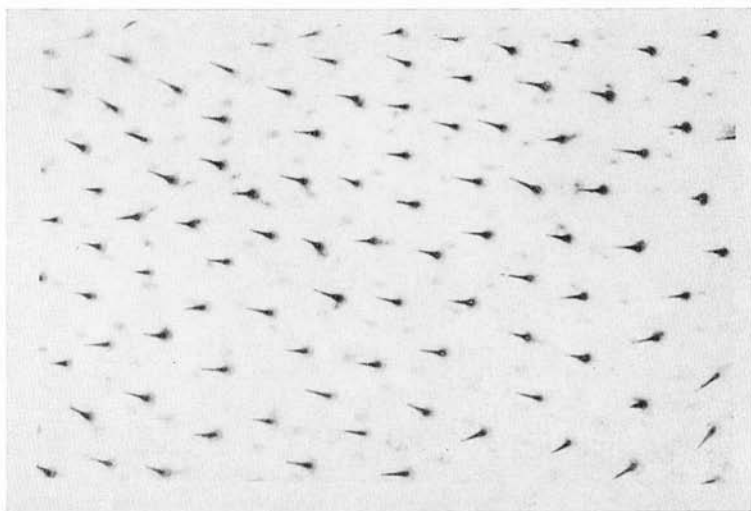


FIG. 2. Bristles covering upper surface of discoidal cell of forewing.

Hindwing

The number of hooks on the hindwing of the queen was significantly lower in the queen (18.2) than in the worker (20.7, Table 8). Haploid drones had significantly more hooks (21.4) than females. Diploid drones had highly or very highly significantly fewer hooks (19.0) than haploids. Thus the number of hooks characteristic for diploid drones was between those for queens and workers, showing a female character.

Hindleg

The queen hind tibia was longer than that of the worker (Table 9), and the drone tibia longer than female tibia. The mean length of the diploid drone tibia was very highly significantly greater than that of the haploid, in lines originating from all queens except the hybrids and one backcross. The overall mean length of the diploid drone tibia was very highly significantly greater than that of the haploid. Thus an extra-long tibia shows a super-male character.

TABLE 1. Length of thorax (mm).

In this and subsequent Tables, *se* = standard error of mean; *o* = difference not statistically significant; *x* = $P < 0.05$, *xx* = $P < 0.01$, *xxx* = $P < 0.001$; different letters before overall means signify that the differences between them are significant.

Race	Queen no.	Diploid drones		Haploid drones		Difference Dip-Hap	Queens		Workers	
		Mean \pm <i>se</i>		Mean \pm <i>se</i>			Mean \pm <i>se</i>		Mean \pm <i>se</i>	
African	128	4.74 \pm 0.030		4.33 \pm 0.039		0.41 xxx	3.48 \pm 0.069	3.41 \pm 0.037		
	141	4.86 \pm 0.029		4.31 \pm 0.021		0.55 xxx	3.80 \pm 0.021	2.96 \pm 0.016		
	146	4.75 \pm 0.026		4.18 \pm 0.032		0.57 xxx	3.76 \pm 0.022	2.98 \pm 0.021		
Italian	144	4.78 \pm 0.031		4.42 \pm 0.027		0.20 xxx	3.38 \pm 0.025	3.11 \pm 0.026		
	154	4.48 \pm 0.028		—		—	3.17 \pm 0.053	3.04 \pm 0.033		
	155	4.68 \pm 0.043		4.27 \pm 0.027		0.37 xxx	—	2.90 \pm 0.019		
Backcross	125	4.53 \pm 0.047		4.09 \pm 0.032		0.44 xxx	3.65 \pm 0.020	2.93 \pm 0.009		
	131	4.58 \pm 0.047		4.18 \pm 0.025		0.40 xxx	3.53 \pm 0.027	2.94 \pm 0.013		
	167	4.60 \pm 0.043		4.43 \pm 0.032		0.12 x	3.64 \pm 0.021	2.92 \pm 0.009		
Hybrids	273	4.40 \pm 0.044		4.20 \pm 0.048		0.20 xx	—	2.98 \pm 0.010		
	439	4.42 \pm 0.021		4.36 \pm 0.022		0.06 x	3.55 \pm 0.029	2.95 \pm 0.019		
	582	4.57 \pm 0.027		4.42 \pm 0.036		0.15 xxx	3.42 \pm 0.044	2.96 \pm 0.014		
Overall mean		a4.59 \pm 0.013		b4.28 \pm 0.0115		0.31 xxx	c3.58 \pm 0.016	d2.98 \pm 0.008		

TABLE 2. Width of thorax (mm). See Table 1 for symbols.

African	128	4.91 \pm 0.048		4.65 \pm 0.042		0.26 xxx	3.56 \pm 0.048	3.34 \pm 0.009
	141	4.94 \pm 0.038		4.62 \pm 0.025		0.32 xxx	3.77 \pm 0.031	3.00 \pm 0.014
	146	4.97 \pm 0.022		4.26 \pm 0.027		0.71 xxx	3.73 \pm 0.032	2.99 \pm 0.022
Italian	144	4.86 \pm 0.048		4.59 \pm 0.020		0.27 xxx	3.70 \pm 0.000	3.20 \pm 0.038
	154	4.77 \pm 0.031		—		—	3.62 \pm 0.049	3.08 \pm 0.026
	155	4.80 \pm 0.061		4.44 \pm 0.030		0.36 xxx	—	3.09 \pm 0.037
Backcross	125	4.60 \pm 0.042		4.32 \pm 0.025		0.28 xxx	3.68 \pm 0.025	3.01 \pm 0.018
	131	4.66 \pm 0.049		4.35 \pm 0.036		0.31 xxx	3.50 \pm 0.026	2.92 \pm 0.024
	167	4.60 \pm 0.060		4.62 \pm 0.045		-0.02 o	3.62 \pm 0.032	2.99 \pm 0.032
Hybrids	273	4.82 \pm 0.049		4.59 \pm 0.047		0.23 xxx	—	3.03 \pm 0.017
	439	4.59 \pm 0.025		4.60 \pm 0.025		-0.01 c	3.75 \pm 0.035	2.99 \pm 0.024
	582	4.93 \pm 0.046		4.83 \pm 0.039		0.10 o	3.49 \pm 0.038	3.08 \pm 0.030
Overall mean		a4.79 \pm 0.015		b4.53 \pm 0.014		0.26 xxx	c3.65 \pm 0.015	d3.05 \pm 0.009

TABLE 3. Thickness of thorax. See Table 1 for symbols.

Race	Queen no.	Diploid drones		Haploid drones		Difference Dip—Hap	Queens		Workers	
		Mean ± se	Mean ± se	Mean ± se	Mean ± se		Mean ± se	Mean ± se		
African	128	6.14 ± 0.040	5.89 ± 0.039	0.25 xxx	4.82 ± 0.084	4.28 ± 0.057				
	141	6.31 ± 0.052	5.82 ± 0.025	0.49 xxx	5.02 ± 0.050	3.74 ± 0.027				
	146	6.13 ± 0.030	5.55 ± 0.044	0.58 xxx	5.19 ± 0.035	3.80 ± 0.023				
Italian	144	6.25 ± 0.055	5.98 ± 0.027	0.27 xxx	5.26 ± 0.074	4.04 ± 0.073				
	154	6.17 ± 0.091	—	—	4.96 ± 0.075	4.02 ± 0.035				
	155	6.23 ± 0.066	5.86 ± 0.038	0.37 xxx	—	4.05 ± 0.042				
Backcross	125	5.92 ± 0.054	5.61 ± 0.031	0.31 xxx	5.19 ± 0.034	3.93 ± 0.025				
	131	5.91 ± 0.052	5.67 ± 0.028	0.24 xxx	4.88 ± 0.031	3.93 ± 0.029				
	167	6.06 ± 0.069	6.03 ± 0.032	0.03 o	5.15 ± 0.090	3.97 ± 0.043				
Hybrids	273	6.07 ± 0.034	5.96 ± 0.048	0.11 x	—	4.09 ± 0.023				
	439	5.92 ± 0.043	5.91 ± 0.049	0.01 o	5.11 ± 0.032	3.83 ± 0.048				
	582	6.08 ± 0.039	6.12 ± 0.033	-0.04 o	4.93 ± 0.054	4.08 ± 0.024				
Overall mean	a6.10 ± 0.015	b5.85 ± 0.015	0.25 xxx	c5.05 ± 0.020	d3.95 ± 0.013					

TABLE 4. Length of forewing (mm). See Table 1 for symbols.

African	128	12.58 ± 0.063	11.98 ± 0.068	0.60 xxx	9.66 ± 0.142	9.40 ± 0.076
	141	12.51 ± 0.059	12.06 ± 0.043	0.45 xxx	9.88 ± 0.034	8.81 ± 0.035
	146	12.47 ± 0.045	11.75 ± 0.076	0.72 xxx	9.74 ± 0.057	8.86 ± 0.036
Italian	144	12.43 ± 0.069	12.00 ± 0.059	0.43 xxx	9.60 ± 0.150	9.25 ± 0.079
	154	12.54 ± 0.043	—	—	9.63 ± 0.106	9.42 ± 0.042
	155	12.53 ± 0.064	12.17 ± 0.059	0.36 xxx	—	9.21 ± 0.038
Backcross	125	12.08 ± 0.085	11.36 ± 0.064	0.72 xxx	9.91 ± 0.038	8.97 ± 0.026
	131	12.14 ± 0.053	11.81 ± 0.093	0.33 xx	9.82 ± 0.049	8.93 ± 0.020
	167	11.81 ± 0.094	12.09 ± 0.050	-0.28 x	10.03 ± 0.051	8.95 ± 0.030
Hybrids	273	12.25 ± 0.075	12.27 ± 0.086	-0.02 o	—	9.29 ± 0.029
	439	12.44 ± 0.049	12.42 ± 0.051	0.02 o	10.10 ± 0.075	9.27 ± 0.027
	582	12.38 ± 0.037	12.24 ± 0.030	0.14 xx	9.63 ± 0.059	8.92 ± 0.026
Overall mean	a12.34 ± 0.023	b12.01 ± 0.024	0.33 xxx	c9.82 ± 0.026	d9.07 ± 0.017	

TABLE 5. Width of forewing (mm). See Table 1 for symbols.

Race	Queen no.	Diploid drones		Haploid drones		Differences Dip—Hap	Queens		Workers	
		Mean ± se	Mean ± se	Mean ± se	Mean ± se		Mean ± se	Mean ± se		
African	128	4.15 ± 0.021	4.03 ± 0.026	0.12 xxx	3.10 ± 0.074	3.27 ± 0.014				
	141	4.08 ± 0.018	3.96 ± 0.017	0.17 xxx	3.23 ± 0.023	3.04 ± 0.012				
	146	4.11 ± 0.017	3.91 ± 0.026	0.20 xx	3.27 ± 0.032	3.07 ± 0.017				
Italian	144	4.04 ± 0.028	3.96 ± 0.024	0.08 x	3.11 ± 0.036	3.17 ± 0.051				
	154	4.09 ± 0.014	—	—	3.16 ± 0.034	3.23 ± 0.014				
	155	3.99 ± 0.034	3.81 ± 0.029	0.18 xxx	—	3.17 ± 0.021				
Backcross	125	3.86 ± 0.027	3.79 ± 0.021	0.07 x	3.25 ± 0.014	3.09 ± 0.026				
	131	3.87 ± 0.024	3.83 ± 0.020	0.03 o	3.20 ± 0.026	3.08 ± 0.011				
	167	3.94 ± 0.035	4.00 ± 0.037	-0.06 o	3.33 ± 0.025	3.12 ± 0.012				
Hybrids	273	3.92 ± 0.018	3.90 ± 0.024	0.02 o	—	3.11 ± 0.016				
	439	3.86 ± 0.022	4.08 ± 0.024	-0.22 xxx	3.36 ± 0.041	3.16 ± 0.009				
	582	3.97 ± 0.019	3.95 ± 0.017	0.02 o	3.09 ± 0.039	3.05 ± 0.011				
Overall mean	a3.99 ± 0.009	b3.93 ± 0.009	0.06 xxx	c3.22 ± 0.014	d3.11 ± 0.006					

TABLE 6. Cubital index of forewing. See Table 1 for symbols.

African	128	1.49 ± 0.05	1.42 ± 0.06	0.07 o	1.82 ± 0.126	1.80 ± 0.061
	141	1.71 ± 0.04	1.76 ± 0.08	-0.05 o	2.57 ± 0.139	2.11 ± 0.053
	146	1.79 ± 0.05	1.87 ± 0.09	-0.08 o	2.07 ± 0.136	2.20 ± 0.059
Italian	144	1.78 ± 0.05	2.12 ± 0.08	-0.34 xxx	2.29 ± 0.120	2.45 ± 0.053
	154	1.83 ± 0.06	—	—	3.87 ± 0.292	2.63 ± 0.054
	155	1.97 ± 0.09	1.84 ± 0.05	0.13 o	—	2.43 ± 0.097
Backcross	125	1.61 ± 0.04	1.83 ± 0.07	-0.22 x	2.89 ± 0.144	2.26 ± 0.041
	131	1.71 ± 0.07	1.64 ± 0.06	0.07 o	2.61 ± 0.081	2.51 ± 0.047
	167	1.71 ± 0.07	1.45 ± 0.06	0.26 xx	2.53 ± 0.106	2.35 ± 0.059
Hybrids	273	2.42 ± 0.09	2.46 ± 0.08	-0.04 o	—	2.39 ± 0.085
	439	2.00 ± 0.13	2.03 ± 0.07	-0.03 o	2.65 ± 0.188	2.37 ± 0.074
	582	1.36 ± 0.04	1.22 ± 0.04	0.14 x	2.01 ± 0.097	1.75 ± 0.054
Overall mean	e1.77 ± 0.025	f1.79 ± 0.029	-0.023 o	g2.55 ± 0.071	h2.28 ± 0.024	

TABLE 7. Number of bristles on forewing. See Table 1 for symbols.

Race	Queen no.	Diploid drones		Haploid drones		Difference Dip-Hap	Queens		Workers	
		Mean \pm se	Mean \pm se	Mean \pm se	Mean \pm se		Mean \pm se	Mean \pm se		
African	128	33.3 \pm 0.77	36.1 \pm 0.89	-2.8 x	137.5 \pm 3.157	75.0 \pm 0.906				
	141	29.6 \pm 0.66	32.3 \pm 0.62	-2.7 xx	135.3 \pm 4.994	77.1 \pm 1.206				
	146	31.1 \pm 0.89	35.7 \pm 0.96	-4.6 xx	135.9 \pm 4.197	74.2 \pm 1.183				
Italian	144	21.0 \pm 0.85	24.2 \pm 0.65	-3.2 xx	117.5 \pm 7.500	53.1 \pm 1.684				
	154	21.8 \pm 0.97	—	—	88.6 \pm 3.742	46.4 \pm 0.798				
	155	20.3 \pm 0.68	26.8 \pm 0.72	-6.5 xxx	—	51.1 \pm 3.128				
Backcross	125	27.4 \pm 0.57	29.6 \pm 0.82	-2.2 x	129.5 \pm 2.497	65.4 \pm 1.080				
	131	26.7 \pm 0.72	28.9 \pm 0.60	-2.2 x	108.8 \pm 1.787	63.2 \pm 1.051				
	167	26.0 \pm 0.73	28.8 \pm 0.63	-2.8 xx	99.1 \pm 4.133	62.5 \pm 1.109				
Hybrids	273	30.0 \pm 0.67	29.5 \pm 0.83	0.5 o	—	66.0 \pm 1.417				
	439	24.6 \pm 0.73	30.7 \pm 0.62	-6.1 xxx	123.3 \pm 4.038	63.3 \pm 1.056				
	582	30.4 \pm 0.46	31.2 \pm 0.84	-0.8 o	157.0 \pm 3.143	82.1 \pm 1.335				
Overall mean		d26.9 \pm 0.310	c30.3 \pm 0.300	3.36 xxx	a124.5 \pm 0.2250	b66.1 \pm 0.247				

TABLE 8. Number of hooks on hind wing. See Table 1 for symbols.

African	128	19.9 \pm 0.52	22.0 \pm 0.57	-2.1 xx	17.9 \pm 0.398	21.1 \pm 0.398
	141	21.3 \pm 0.39	21.5 \pm 0.36	-0.2 xx	17.3 \pm 0.700	21.5 \pm 0.252
	146	19.0 \pm 0.46	21.8 \pm 0.49	-2.8 xxx	18.3 \pm 0.359	21.1 \pm 0.318
Italian	144	16.4 \pm 0.38	19.3 \pm 0.29	-2.9 xxx	17.0 \pm 1.00	19.1 \pm 0.398
	154	18.1 \pm 0.48	—	—	17.2 \pm 0.494	19.3 \pm 0.304
	155	18.1 \pm 0.48	20.6 \pm 0.38	-2.5 xxx	—	20.0 \pm 0.436
Backcross	125	19.3 \pm 0.44	21.4 \pm 0.41	-2.2 xxx	18.2 \pm 0.380	20.7 \pm 0.360
	131	18.4 \pm 0.52	22.0 \pm 0.36	-3.6 xxx	18.2 \pm 0.348	19.7 \pm 0.311
	167	18.8 \pm 0.51	23.6 \pm 0.36	-4.8 xxx	19.8 \pm 0.400	21.9 \pm 0.244
Hybrids	273	21.3 \pm 0.54	22.3 \pm 0.47	-1.0 o	—	21.5 \pm 0.209
	439	16.3 \pm 0.35	18.6 \pm 0.62	-2.3 xx	18.0 \pm 0.577	19.3 \pm 0.292
	582	21.4 \pm 0.52	22.9 \pm 0.38	-1.5 x	18.8 \pm 0.429	22.5 \pm 0.259
Overall mean		c19.0 \pm 0.167	a21.4 \pm 0.153	-2.4 xxx	d18.2 \pm 0.167	b20.7 \pm 0.112

TABLE 9. Length of hind leg tibia (mm). See Table 1 for symbols.

Race	Queen no.	Diploid drones		Haploid drones		Difference Dip-Hap	Queens		Workers	
		Mean \pm se		Mean \pm se			Mean \pm se		Mean \pm se	
African	128	4.13 \pm 0.023		4.03 \pm 0.028		0.10 xx	3.50 \pm 0.043	3.38 \pm 0.015		
	141	4.26 \pm 0.017		4.06 \pm 0.015		0.20 xxx	3.76 \pm 0.024	3.15 \pm 0.021		
	146	4.24 \pm 0.011		3.95 \pm 0.026		0.29 xxx	3.75 \pm 0.032	3.16 \pm 0.013		
Italian	144	4.17 \pm 0.032		4.03 \pm 0.013		0.14 xxx	3.69 \pm 0.037	3.36 \pm 0.027		
	154	4.11 \pm 0.016		—		—	3.67 \pm 0.057	3.34 \pm 0.020		
	155	4.25 \pm 0.028		4.08 \pm 0.020		0.17 xxx	—	3.30 \pm 0.019		
Backcross	125	4.11 \pm 0.022		3.89 \pm 0.029		0.22 xxx	3.73 \pm 0.023	3.10 \pm 0.007		
	131	4.09 \pm 0.033		3.88 \pm 0.018		0.21 xxx	3.79 \pm 0.030	3.20 \pm 0.013		
	167	4.16 \pm 0.042		4.10 \pm 0.015		0.06 o	3.89 \pm 0.021	3.27 \pm 0.013		
Hybrids	273	4.17 \pm 0.030		4.13 \pm 0.018		0.04 o	—	3.26 \pm 0.015		
	439	4.15 \pm 0.018		4.20 \pm 0.025		-0.05 o	3.68 \pm 0.041	3.19 \pm 0.010		
	582	4.10 \pm 0.013		4.08 \pm 0.018		0.02 o	3.49 \pm 0.034	3.18 \pm 0.013		
Overall mean		a4.16 \pm 0.008		b4.04 \pm 0.009		0.12 xxx	c3.70 \pm 0.016	d3.24 \pm 0.007		

TABLE 10. Width of hind leg tibia (mm). See Table 1 for symbols.

African	128	1.18 \pm 0.014		1.10 \pm 0.011		0.08 xxx	1.20 \pm 0.025	1.21 \pm 0.017
	141	1.21 \pm 0.013		1.12 \pm 0.008		0.09 xxx	1.10 \pm 0.015	1.04 \pm 0.008
	146	1.23 \pm 0.009		1.12 \pm 0.013		0.11 xxx	1.12 \pm 0.022	1.07 \pm 0.010
Italian	144	1.19 \pm 0.009		1.12 \pm 0.009		0.07 xxx	1.23 \pm 0.049	1.18 \pm 0.031
	154	1.16 \pm 0.008		—		—	1.20 \pm 0.012	1.11 \pm 0.010
	155	1.15 \pm 0.014		1.08 \pm 0.011		0.07 xxx	—	1.12 \pm 0.019
Backcross	125	1.14 \pm 0.007		1.07 \pm 0.012		0.07 xxx	1.24 \pm 0.015	1.06 \pm 0.008
	131	1.17 \pm 0.010		1.12 \pm 0.010		0.05 xxx	1.18 \pm 0.019	1.09 \pm 0.008
	167	1.19 \pm 1.011		1.15 \pm 0.009		0.04 xxx	1.24 \pm 0.017	1.13 \pm 0.008
Hybrids	273	1.12 \pm 0.016		1.13 \pm 0.012		-0.01 o	—	1.10 \pm 0.008
	439	1.15 \pm 0.001		1.13 \pm 0.010		0.02 o	1.28 \pm 0.012	1.12 \pm 0.007
	582	1.20 \pm 0.011		1.22 \pm 0.013		-0.02 o	1.15 \pm 0.014	1.11 \pm 0.023
Overall mean		b1.17 \pm 0.004		c1.12 \pm 0.004		0.05 xxx	a1.19 \pm 0.008	e1.11 \pm 0.004

TABLE 11. Length of hind leg basitarsus (mm). See Table 1 for symbols.

Race	Queen no.	Diploid drones		Haplodiploid drones		Differences Dip—Hap	Queens		Workers	
		Mean ± se	Mean ± se	Mean ± se	Mean ± se		Mean ± se	Mean ± se		
African	128	2.63 ± 0.020	2.64 ± 0.025	-0.01 0	2.32 ± 0.026	2.11 ± 0.025				
	141	2.77 ± 0.018	2.62 ± 0.017	0.15 xxx	2.48 ± 0.029	1.95 ± 0.013				
	146	2.72 ± 0.014	2.57 ± 0.021	0.15 xxx	2.39 ± 0.030	1.97 ± 0.011				
Italian	144	2.65 ± 0.022	2.54 ± 0.018	0.11 xxx	2.37 ± 0.025	2.10 ± 0.007				
	154	2.64 ± 0.016	—	—	2.12 ± 0.036	2.05 ± 0.016				
	155	2.70 ± 0.028	2.57 ± 0.015	0.13 xxx	—	2.12 ± 0.017				
Backcross	125	2.72 ± 0.018	2.54 ± 0.020	0.18 xxx	2.47 ± 0.025	2.03 ± 0.010				
	131	2.65 ± 0.027	2.58 ± 0.015	0.07 x	2.29 ± 0.023	2.01 ± 0.009				
	167	2.69 ± 0.033	2.72 ± 0.018	-0.03 0	2.46 ± 0.032	2.03 ± 0.013				
Hybrids	273	2.63 ± 0.020	2.61 ± 0.014	0.02 0	—	2.04 ± 0.010				
	439	2.59 ± 0.011	2.65 ± 0.020	-0.06 x	2.47 ± 0.037	1.95 ± 0.008				
	582	2.65 ± 0.013	2.64 ± 0.011	0.01 0	2.32 ± 0.030	1.98 ± 0.009				
Overall mean	a2.67 ± 0.007	b2.61 ± 0.006	0.06 xxx	c2.37 ± 0.015	d2.03 ± 0.005					

TABLE 12. Width of hind leg basitarsus (mm). See Table 1 for symbols.

African	128	1.36 ± 0.014	1.30 ± 0.012	0.06 xx	1.11 ± 0.013	1.27 ± 0.012
	141	1.40 ± 0.015	1.29 ± 0.009	0.11 xxx	1.20 ± 0.016	1.13 ± 0.007
	146	1.37 ± 0.019	1.26 ± 0.011	0.11 xxx	1.16 ± 0.010	1.16 ± 0.007
Italian	144	1.37 ± 0.014	1.33 ± 0.011	0.04 x	1.15 ± 0.037	1.21 ± 0.019
	154	1.28 ± 0.013	—	—	1.21 ± 0.009	1.19 ± 0.011
	155	1.25 ± 0.014	1.18 ± 0.014	0.07 xxx	—	1.14 ± 0.009
Backcross	125	1.30 ± 0.015	1.21 ± 0.014	0.09 xxx	1.17 ± 0.012	1.17 ± 0.006
	131	1.32 ± 0.014	1.26 ± 0.012	0.06 xx	1.23 ± 0.012	1.17 ± 0.005
	167	1.32 ± 0.018	1.34 ± 0.013	-0.02 0	1.16 ± 0.012	1.16 ± 0.008
Hybrids	273	1.29 ± 0.013	1.28 ± 0.014	0.01 0	—	1.14 ± 0.006
	439	1.29 ± 0.011	1.34 ± 0.009	-0.05 xxx	1.13 ± 0.011	1.19 ± 0.005
	582	1.35 ± 0.013	1.31 ± 0.014	0.04 x	1.14 ± 0.017	1.13 ± 0.008
Overall mean	a1.33 ± 0.005	b1.28 ± 0.005	0.05 xxx	c1.17 ± 0.005	d1.17 ± 0.003	

The hind tibia was wider in the queen than in the worker. In diploid drones the overall mean width of tibia was very highly significantly greater than in haploid drones. The widths of tibia for both types of drone (diploid 1.17 mm, haploid 1.12 mm) were between those of queens (1.19 mm) and workers (1.11 mm). The width of the diploid drone tibia was closer to that of the queen, and that of the haploid drone was almost identical to that of the worker. Thus the width of the diploid drone tibia showed a caste character. This exemplifies the importance of including the queen in all comparative studies. If tibial width had not been measured for queens, this character would have been considered super-male in diploid drones. Table 10, however, shows that the relation between tibial width in both types of drone and the females varied in different lines. Width of tibia showed intersex character in diploid drones originating from one African queen (128), and super-male character in diploids originating from the other two. The mean values for diploid Italian drones were between those for queens and workers, thus showing a female character. The tibial length of diploid drones derived from backcrosses showed a caste character. Since no significant difference was found between the tibial lengths of haploid and diploid drones derived from hybrid queens, those diploid drones showed a male character.

The hind basitarsi of the queens were all longer than those of the workers (Table 11), but the width relation varied (Table 12). The overall mean length was greater in the queens, but the width was the same. The basitarsi of both types of drone were longer and wider than those of the females. The overall means of both dimensions were very highly significantly greater in diploid than in haploid drones. Thus the size of basitarsus of diploid drones showed a super-male character.

Discussion and Conclusions

Most differences between the mean values for haploid and diploid drones were significant in pure lines of bees and in their backcrosses. Many of the differences for hybrid lines were not significant. Results are summarized in Table 13.

TABLE 13. Size of different parts of the thorax of haploid (H) and diploid (D) drones and of queens (Q) and workers (W) arranged in order of increasing size (mm or no.)

Table no.	Thorax parts	Smallest		Larger			Largest	D character		
1	Length of thorax	W	2.98	Q	3.58	H	4.28	D	4.59	super-male
2	Width of thorax	W	3.05	Q	3.65	H	4.53	D	4.79	super-male
3	Thickness of thorax	W	3.95	Q	5.05	H	5.85	D	6.10	super-male
4	Length of forewing	W	9.07	Q	9.82	H	12.01	D	12.34	super-male
5	Width of forewing	W	3.11	Q	3.22	H	3.93	D	3.99	super-male
6	Cubital index	D	1.77	H	1.79	W	2.28	Q	2.55	male
7	No. bristles on forewing	D	26.9	H	30.3	W	66.1	Q	124.5	super-male
8	No. hooks on hind wing	Q	18.2	D	19.0	W	20.7	H	21.4	female
9	Length of hind tibia	W	3.24	Q	3.70	H	4.04	D	4.16	super-male
10	Width of hind tibia	W	1.11	H	1.12	D	1.17	Q	1.19	caste
11	Length of hind basitarsus	W	2.03	Q	2.37	H	2.61	D	2.67	super-male
12	Width of hind basitarsus	W,Q	1.17	W,Q	1.17	H	1.28	D	1.33	super-male

Mostly, the thorax and its appendages were significantly larger in diploid than in haploid drones, but the number of bristles on the forewing and the number of hooks on the hindwing were significantly lower, and the cubital index was similar in haploid and diploid. The dimensions of the drone thorax showed different inter-relationships from those of the queen and worker, and four types of character (super-male, male, caste and female) were found:

- (a) For the thorax, forewing, and most dimensions of the leg, the sequence (in increasing size) was W, Q, H, D.
The sequence for the number of bristles on the forewing was nearly reversed, D, H, W, Q. In both sequences the diploid drones were farthest away from the females, thus showing super-male characters.
- (b) The cubital index was similar in diploid and haploid drones, thus showing a male character.
- (c) For the width of tibia the sequence was W, H, D, Q. The diploid drone was closer to the queen, and the haploid to the worker: the diploid drone showed a caste character.
- (d) For the number of hooks on the hindwing the sequence was Q, D, W, H; diploid drones showed a female character.

Of the characters presented in this paper, 7 had been studied by Chaud-Netto (1975); 5 gave results considerably different from those he obtained. He reported that diploid drones had a shorter thorax than haploids, whereas our diploid drones from African queens had a very highly significantly longer thorax. Chaud-Netto reported a 0·37 mm difference in length of forewing between diploid and haploid drones, whereas our difference for African drones ranged from 0·45 mm to 0·72 mm. Also, he found that the hind tibia was smaller, whereas here it was very highly significantly larger for African drones. Chaud-Netto found the tarsal length to be 0·20 mm shorter, whereas here it was 0·01 mm shorter (once) and 0·15 mm longer (twice). Thus the thorax and its appendages reported here were larger in diploids than in haploids, while they were smaller (or the differences were lower) in Chaud-Netto's studies. The two sets of results will be discussed later.

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