

COMPARATIVE BIOMETRICAL INVESTIGATION ON DIPLOID DRONES OF THE HONEYBEE

III. THE ABDOMEN, AND WEIGHT *

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Summary

A total of 9268 measurements were made on abdominal segments 4 and 5 of 271 diploid and 264 haploid drones, 109 queens and 236 workers, originating from 12 queens of *Apis mellifera adansonii*, *Apis mellifera ligustica* and some crosses. Also 518 diploid and haploid drones were weighed individually.

Abdominal segments of diploid drones were larger than those of haploids. Out of 12 characters studied, 4 were smaller in the females, and as many as 8 were larger in at least one female caste, than those in the haploid drones. Therefore the size of certain abdominal parts of diploid drones showed different relations from those of haploids and females. Four segment sizes showed super-male character and out of 8 others, 4 showed caste character, 2 intersex, 1 female and 1 super-female character.

The pure race diploid drones were about 25% heavier than the haploids, showing a super-male character.

Introduction

This paper presents the first biometrical investigation on the abdomen and on the weight of diploid drones, and provides comparisons with haploid drones, workers and queens (Woyke, 1977, 1978).

Materials and Methods

The same bees were used as in Parts 1 and 2. Abdominal measurements were taken of 271 diploid drones, 264 haploid drones, 109 queens and 236 workers. The bees originated from 12 queens of *Apis mellifera adansonii*, *A. m. ligustica*, backcross of Italian queens to drones from F₁ hybrid queens of the two races and some hybrids. Tergites and sclerites of abdominal segments 4 and 5 were measured. When possible 25 individuals of each line originating from the 12 queens were sampled (Woyke, 1977, Table 1). During dissection of the reproductive organs several abdomens were lost or damaged, and therefore some characters were measured on fewer individuals. Only one abdomen was available from two queens originating from No. 144, and therefore no standard error of the mean for that queen is given in Tables 1-12. A total of 9268 measurements were made, Fig. 1 showing their exact locations.

The weights of 272 diploid and 246 haploid drones, 0-1 day old, originating from 12 queens were obtained by the following method. The diploid drones were reared as described by Woyke (1969), and the queens, workers and haploid drones by standard methods. They were caged for a few days before they emerged from the cells as adults. All newly emerged individuals were collected daily, and the haploid and diploid drones

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weighed. All were then killed, and the reproductive organs of the drones dissected (Woyke 1973, 1974). The insects were preserved in 70% alcohol, until measurements could be made of tergites and sclerites of segments 4 and 5 (Fig. 1), numbered according to Snodgrass (1956).

Student's *t* test was applied to find significant differences between overall means.

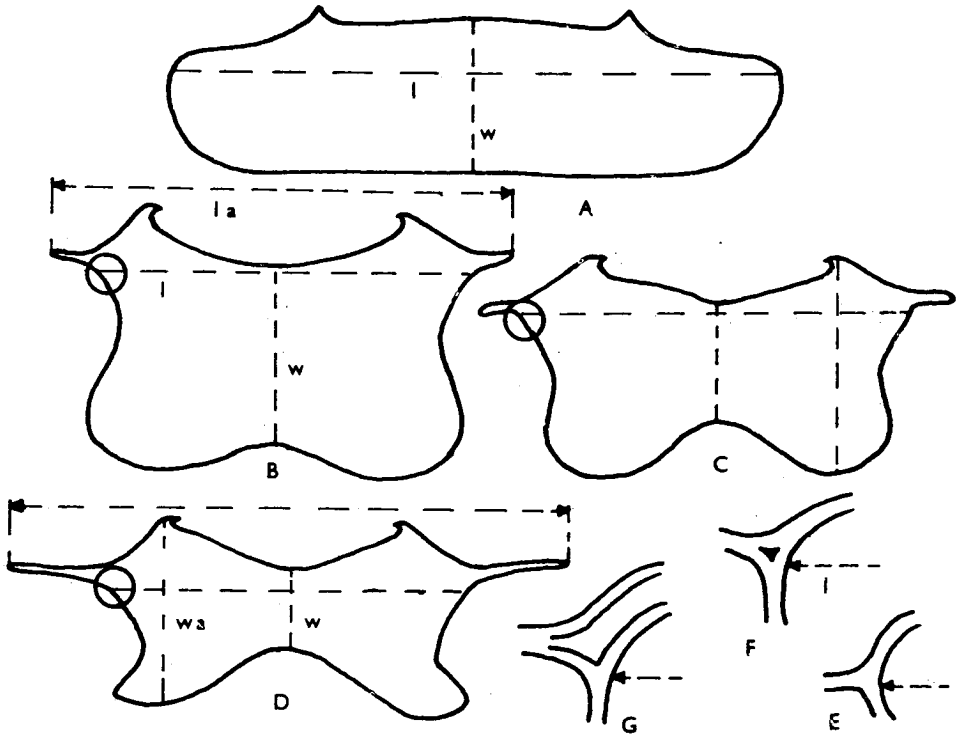


FIG. 1. Identification of abdominal characters measured.

A Length (*l*) and width (*w*) of tergite.

B Queen, C Worker, D Drone: Length of sternite with lateral apodemes (*l_a*) and without them (*l*), width with front apodeme (*w_a*) and without it (*w*).

E Queen, F Worker, D Drone: Areas circles in B, C, D, enlarged to show point on tergites to which the length without apodemes was measured.

Results

Fourth abdominal segment

The tergite of segment 4 was longer in the queen than in the worker (Table 1), and both types of drone had longer tergites than the females. The African diploid drone and some backcrosses had longer tergites than the haploids. No significant differences were found between the two types of drone in pure Italian and some crosses, but very highly significantly shorter tergites were found in diploids from one hybrid line. The overall mean length of this tergite was very highly significantly greater in the diploids than in haploids. Thus the length of tergite of diploid drones shows a super-male character.

The queens had much wider tergites than the workers (Table 2). Most of the diploid drones had wider segments than haploids, but statistically significant differences were absent in some lines, and in some crosses significantly narrower tergites were found.

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.

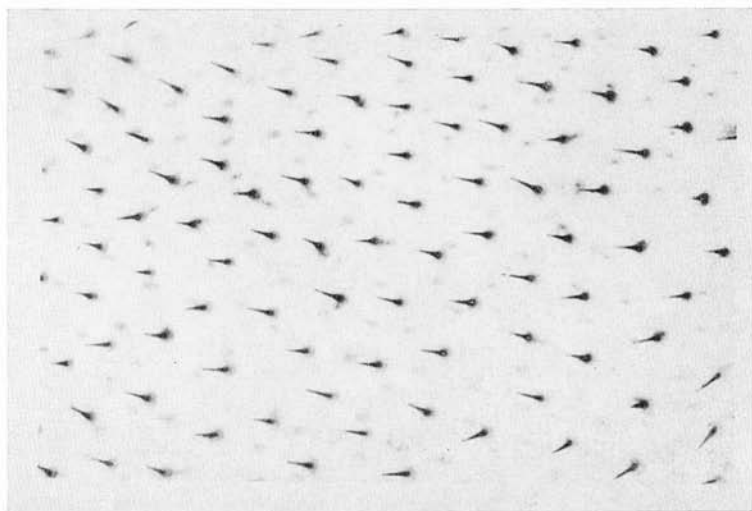


FIG. 2. Bristles covering upper surface of discoidal cell of forewing.

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 3. Length (mm) of fourth sternite (with lateral apodemes) of diploid and haploid drones, and of queen and worker. See Table 1 for symbols.

Race	Queen no.	Diploid drones		Haploid drones		Difference Dtp—Hap	Queens		Workers	
		Mean ± se	Mean ± se	Mean ± se	Mean ± se		Mean ± se	Mean ± se		
African	128	7.799 ± 0.037	7.468 ± 0.067	0.331 xxx	6.791 ± 0.130	6.564 ± 0.039				
	141	7.779 ± 0.061	7.720 ± 0.087	0.059 o	6.890 ± 0.031	6.055 ± 0.021				
	146	7.688 ± 0.027	7.525 ± 0.053	0.163 xx	6.964 ± 0.050	5.980 ± 0.032				
Italian	144	7.789 ± 0.030	7.547 ± 0.044	0.242 xxx	7.161	6.346 ± 0.075				
	154	7.799 ± 0.037	—	—	7.117 ± 0.133	6.304 ± 0.053				
	155	7.905 ± 0.050	7.562 ± 0.063	0.340 xxx	—	6.350 ± 0.042				
Backcross	125	7.621 ± 0.041	7.305 ± 0.047	0.316 xxx	7.033 ± 0.064	5.931 ± 0.026				
	131	7.522 ± 0.026	7.211 ± 0.023	0.311 xxx	6.905 ± 0.041	5.917 ± 0.019				
	167	7.853 ± 0.064	7.705 ± 0.029	0.148 x	7.492 ± 0.017	6.119 ± 0.029				
Hybrid	273	7.409 ± 0.029	7.705 ± 0.198	-0.296 o	—	6.193 ± 0.016				
	439	7.591 ± 0.048	7.483 ± 0.038	0.108 o	7.166 ± 0.064	6.161 ± 0.032				
	582	7.523 ± 0.040	7.430 ± 0.047	0.093 o	6.305 ± 0.061	5.729 ± 0.025				
Overall mean	a7.690 ± 0.015	b7.448 ± 0.019	0.242 xxx	c6.920 ± 0.039	d6.067 ± 0.017					

TABLE 4. Length (mm) of fourth sternite (without lateral apodemes) of diploid and haploid drones, and of queen and worker. See Table 1 for symbols.

African	128	5.280 ± 0.022	5.013 ± 0.034	0.267 xxx	5.179 ± 0.081	5.512 ± 0.024
	141	5.393 ± 0.035	5.107 ± 0.023	0.286 xxx	5.546 ± 0.045	4.998 ± 0.023
	146	5.240 ± 0.025	5.022 ± 0.029	0.218 xxx	5.338 ± 0.040	5.004 ± 0.024
Italian	144	5.043 ± 0.036	4.860 ± 0.036	0.183 xxx	5.680	5.112 ± 0.088
	154	5.026 ± 0.022	—	—	5.652 ± 0.094	5.150 ± 0.045
	155	5.363 ± 0.020	4.945 ± 0.023	0.418 xxx	—	5.245 ± 0.019
Backcross	125	4.988 ± 0.023	4.692 ± 0.035	0.296 xxx	5.477 ± 0.039	4.924 ± 0.020
	131	4.919 ± 0.024	4.682 ± 0.018	0.237 xxx	5.453 ± 0.043	4.929 ± 0.018
	167	5.100 ± 0.045	4.945 ± 0.022	0.155 xx	5.749 ± 0.059	5.149 ± 0.024
Hybrid	273	4.889 ± 0.087	4.856 ± 0.092	0.033 o	—	5.062 ± 0.015
	439	5.223 ± 0.021	4.979 ± 0.028	0.244 xxx	5.522 ± 0.045	5.220 ± 0.018
	582	5.021 ± 0.024	4.885 ± 0.030	0.136 xxx	5.085 ± 0.050	4.791 ± 0.018
Overall mean	b5.123 ± 0.013	d4.973 ± 0.012	0.150 xxx	a5.482 ± 0.026	c5.052 ± 0.013	

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 9. Length (mm) of fifth sternite (with lateral apodemes) of diploid and haploid drones, and of queen and worker. 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
African	128	8.085	± 0.039	7.818	± 0.073	0.267 xxx	6.735	± 0.152	6.603	± 0.043
	141	8.100	± 0.037	7.725	± 0.073	0.375 xxx	6.648	± 0.051	5.981	± 0.021
	146	8.005	± 0.023	7.824	± 0.049	0.181 xx	6.697	± 0.057	5.858	± 0.040
Italian	144	7.970	± 0.046	7.809	± 0.048	0.161 x	7.062	—	6.316	± 0.058
	154	8.053	± 0.034	—	—	—	7.002	± 0.130	6.162	± 0.059
	155	7.843	± 0.064	7.873	± 0.039	-0.030 o	—	—	6.214	± 0.067
Backcross	125	7.907	± 0.042	7.547	± 0.047	0.360 xxx	6.944	± 0.059	5.774	± 0.031
	131	7.576	± 0.037	7.517	± 0.024	0.059 o	6.663	± 0.020	5.705	± 0.025
	167	7.789	± 0.053	7.932	± 0.019	-0.143 x	7.181	± 0.071	6.006	± 0.008
Hybrid	273	7.865	± 0.040	7.260	± 0.149	0.605 xx	—	—	6.025	± 0.017
	439	7.700	± 0.052	7.754	± 0.053	-0.054 o	6.994	± 0.033	6.090	± 0.021
	582	7.850	± 0.039	7.777	± 0.044	0.073 o	6.177	± 0.048	5.680	± 0.022
Overall mean		a7.862	± 0.016	b7.723	± 0.019	0.139 xxx	c6.291	± 0.036	d5.945	± 0.015

TABLE 10. Length (mm) of fifth sternite (without apodemes) of diploid and haploid drones, and of queen and worker. See Table 1 for symbols.

African	128	5.428	± 0.034	5.176	± 0.040	0.252 xxx	4.457	± 0.103	5.517	± 0.026
	141	5.546	± 0.033	5.240	± 0.021	0.306 xxx	5.260	± 0.081	4.969	± 0.021
	146	5.413	± 0.027	5.143	± 0.031	0.270 xxx	5.062	± 0.045	4.937	± 0.027
Italian	144	5.117	± 0.031	4.830	± 0.035	0.287 xxx	5.284	—	5.013	± 0.088
	154	5.129	± 0.027	—	—	—	5.142	± 0.059	5.065	± 0.044
	155	5.441	± 0.041	5.036	± 0.023	0.405 xxx	—	—	5.235	± 0.038
Backcross	125	5.132	± 0.026	4.801	± 0.037	0.331 xxx	5.201	± 0.045	4.855	± 0.029
	131	4.840	± 0.040	4.781	± 0.029	0.059 o	5.102	± 0.043	4.717	± 0.023
	167	5.270	± 0.046	5.043	± 0.039	0.227 xxx	5.467	± 0.044	5.038	± 0.024
Hybrid	273	5.149	± 0.056	4.906	± 0.033	0.243 xx	—	—	4.988	± 0.016
	439	5.339	± 0.027	5.087	± 0.024	0.252 xxx	5.346	± 0.040	5.206	± 0.014
	582	5.161	± 0.028	5.046	± 0.032	0.115 xx	4.926	± 0.030	4.791	± 0.020
Overall mean		a5.235	± 0.049	c4.966	± 0.013	0.269 xxx	b5.181	± 0.023	b64.979	± 0.014

TABLE 11. Width (mm) of fifth sternite (with front apodeme) of diploid and haploid drones, and of queen and worker. 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	2.973 ± 0.018	2.970 ± 0.018	0.003 o	3.883 ± 0.059	3.108 ± 0.036				
	141	2.963 ± 0.016	2.807 ± 0.028	0.156 xxx	3.834 ± 0.015	2.759 ± 0.009				
	146	3.122 ± 0.021	2.933 ± 0.021	0.189 xxx	3.883 ± 0.027	2.829 ± 0.013				
Italian	144	3.007 ± 0.026	2.960 ± 0.012	0.047 o	3.901	2.994 ± 0.040				
	154	2.973 ± 0.015	—	—	3.849 ± 0.060	2.906 ± 0.026				
	155	3.032 ± 0.042	2.894 ± 0.012	0.138 xxx	—	2.857 ± 0.027				
Backcross	125	3.000 ± 0.018	2.691 ± 0.020	0.309 xxx	3.783 ± 0.018	2.701 ± 0.017				
	131	2.871 ± 0.015	2.791 ± 0.013	0.080 xxx	3.759 ± 0.023	2.637 ± 0.015				
	167	3.064 ± 0.030	2.936 ± 0.018	0.128 xx	3.958 ± 0.033	2.852 ± 0.010				
Hybrid	273	2.864 ± 0.040	2.706 ± 0.018	0.158 xx	—	2.839 ± 0.010				
	439	2.913 ± 0.036	2.901 ± 0.046	0.012 o	3.886 ± 0.025	2.800 ± 0.018				
	582	3.021 ± 0.015	2.981 ± 0.015	0.040 o	3.968 ± 0.058	2.864 ± 0.010				
Overall mean	a2.987 ± 0.008	b2.875 ± 0.010	0.112 xxx	c3.849 ± 0.012	d2.818 ± 0.009					

TABLE 12. Width (mm) of fifth sternite (without apodeme) of diploid and haploid drones, and of queen and worker. See Table 1 for symbols.

African	128	1.235 ± 0.011	1.217 ± 0.010	0.018 o	2.555 ± 0.059	1.867 ± 0.042
	141	1.237 ± 0.008	1.211 ± 0.017	0.026 o	2.642 ± 0.040	1.648 ± 0.012
	146	1.219 ± 0.005	1.155 ± 0.013	0.064 xxx	2.673 ± 0.015	1.736 ± 0.011
Italian	144	1.285 ± 0.007	1.265 ± 0.016	0.020 o	2.790	1.898 ± 0.030
	154	1.218 ± 0.027	—	—	2.614 ± 0.044	1.764 ± 0.013
	155	1.321 ± 0.010	1.311 ± 0.013	0.010 o	—	1.922 ± 0.027
Backcross	125	1.235 ± 0.009	1.210 ± 0.010	0.025 o	2.674 ± 0.018	1.566 ± 0.014
	131	1.259 ± 0.009	1.235 ± 0.007	0.024 x	2.553 ± 0.017	1.660 ± 0.010
	167	1.249 ± 0.006	1.301 ± 0.011	-0.052 xxx	2.837 ± 0.020	1.792 ± 0.018
Hybrid	273	1.212 ± 0.026	1.239 ± 0.016	-0.027 o	—	1.785 ± 0.010
	439	1.262 ± 0.007	1.269 ± 0.009	-0.007 o	2.711 ± 0.043	1.792 ± 0.011
	582	1.253 ± 0.009	1.256 ± 0.010	-0.0043 xx	2.656 ± 0.040	1.876 ± 0.008
Overall mean	c1.249 ± 0.003	c1.240 ± 0.005	0.009 o	a2.662 ± 0.014	b1.759 ± 0.008	

TABLE 13. Weight of haploid and diploid drones (mg).

Race	Queen no.	Diploid drones		Haploid drones		Difference Dip-Hap
		No.	Mean \pm se	No.	Mean \pm se	
African	128	21	275.5 \pm 5.56	25	243.5 \pm 3.92	32.00 xxx
	141	27	293.3 \pm 4.70	25	225.1 \pm 2.68	68.20 xxx
	146	24	252.2 \pm 6.90	13	209.3 \pm 5.72	42.90 xxx
Italian	144	25	278.7 \pm 6.37	25	225.9 \pm 3.76	52.80 xxx
	154	25	273.9 \pm 5.28	—	—	—
	155	19	278.0 \pm 5.87	25	217.5 \pm 4.86	60.50 xxx
Backcross	125	25	231.1 \pm 5.79	26	216.3 \pm 2.41	14.80 x
	131	25	246.7 \pm 6.59	25	223.5 \pm 3.06	23.20 xx
	167	24	254.3 \pm 8.34	25	230.7 \pm 4.47	23.60 x
Hybrid	163	25	228.7 \pm 2.75	25	219.6 \pm 2.01	9.10 x
	91	21	256.2 \pm 4.90	12	213.9 \pm 6.88	42.30 xxx
	212	11	277.0 \pm 5.77	20	261.5 \pm 3.39	15.45 x
Overall mean		272	262.1 \pm 5.74	246	226.0 \pm 3.96	36.10 xxx

TABLE 14. Size (mm) of different abdomen parts of haploid (H) and diploid (D) drone and of queen (Q) and worker (W) as well as weight (mg) of drones, arranged in increasing sequence.

Table no.	Abdomen part and weight	Smallest	Larger	Largest	D character	
Fourth abdominal segment						
1	Length of tergite	W 9.233	Q 10.986	H 13.249	D 13.525	super-male
2	Width of tergite	W 2.231	H 2.893	D 2.923	Q 3.199	caste
3	Length of sternite with apodemes	W 6.067	W 6.920	H 7.448	D 7.690	super-male
4	Length of sternite without apodemes	H 4.973	W 5.052	D 5.123	Q 5.482	female
5	Width of sternite with apodeme	W 2.829	H 2.847	D 2.962	Q 3.691	caste
6	Width of sternite without apodeme	H 1.264	D 1.278	W 1.699	Q 2.468	intersex
Fifth abdominal segment						
7	Length of tergite	W 8.665	Q 10.635	H 12.899	D 13.174	super-male
8	Width of tergite	W 2.173	H 2.857	D 2.888	Q 3.131	caste
9	Length of sternite with apodemes	W 5.945	Q 6.291	H 7.723	D 7.862	super-male
10	Length of sternite without apodemes	H 4.966	W 4.979	Q 5.181	D 5.235	super-female
11	Width of sternite with apodeme	W 2.818	H 2.875	D 2.987	Q 3.849	caste
12	Width of sternite without apodeme	H 1.240	D 1.249	W 1.759	Q 2.662	intersex
13	Weight of bee	W	Q	H 226.0	D 262.1	super-male

The overall mean width of tergite 4 was higher in diploid than in haploid drones. In relation to the females, the sizes of the drones were between those of the queen and worker. The width of tergite for diploid drones (2.923 mm) was closer to that in the queens (3.199 mm), while the width for the haploids was closer to that in the workers (2.231 mm) than to that in the diploids. Here the diploid drone shows a caste character. The importance of including queens in the comparison should be noted: had they been omitted, the width of tergite for diploid drones would be classified as a super-male character.

The sternite (with the lateral apodemes) was longer in queens than in the workers (Table 3). The sternites of both types of drone were longer than those of the females. In most cases diploid drones had significantly longer sternites than the haploids, but in one pure line, and the hybrids, the difference was not found to be significant. In all diploid drones sternite 4 was very highly significantly longer than in the haploid samples, thus showing a super-male character.

The sternite without lateral apodemes was longer in queens than in workers (Table 4), and also longer in diploid than in haploid drones, the one exception being hybrid line 273, but this was not significant statistically. In all other lines the sternite was highly or very highly significantly longer in diploid drones than in the haploids. Length of sternite was found to be one of the best abdominal characters to use for discriminating between diploid and haploid drones. The difference between the overall means of this character for the two types of drone was very highly significant. The sternite of the haploid drone was shorter (4.973 mm) than those of the females, and the length for diploid drones (5.123 mm) was between those for the workers (5.052 mm) and the queens (5.482 mm). Thus the length of sternite 4 without apodemes showed a female character in diploid drones. It is important to make two sets of measurements (with and without apodemes) when assessing this character, as the presence of apodemes changes it from female-like to super-male.

Sternite 4 (with the front apodeme) was much wider in queens than in workers (Table 5). The diploid drones had significantly wider sternites than haploid drones in all pure lines and backcrosses. Diploid drones usually had very highly significantly wider sternites than haploids. The measurements for drones were between those for the females, the width of the diploid drone sternite (2.962 mm) being closer to that of the queen (3.691 mm), whereas that of the haploid (2.847 mm) was closer to the worker (2.829 mm). Here the diploid drone shows a caste character, although if the dimensions for the queen were ignored, this diploid drone character would be considered super-male.

Sternite 4 without the front apodeme was also much wider in queens than in workers (Table 6). Most of the diploid drones had wider sternites than the haploids, but in 11 lines sampled the difference between them was statistically significant in only three. No significant difference was found in five other lines, and significantly narrower diploid sternites were found in three crosses. The overall mean was still significantly higher in diploid than in haploid drones. The sternites of both types of drone were narrower than those of the females, and this dimension for diploid drones was closer to the female than that of the haploids. Thus in diploid drones the width of sternite 4 without the apodeme shows an intersex character. Again, different relations with the females can be obtained if the apodemes are included in the measurements.

Fifth abdominal segment

The relations between the dimensions of the tergites and sternites from segment 5 were very similar to those found in segment 4 (Tables 7-11). The length of tergite 5 (Table 7) discriminates better between diploid and haploid drones than does its width (Table 8).

The length of sternite 5 without lateral apodemes (Table 10), when compared with that of sternite 4 (Table 4), was the best dimension to use for discriminating between the two types of drone. The width of tergite 5 without the apodeme was the least reliable discriminating value (Table 12). The relations of different dimensions between the two types of drone and the females were also almost identical for segments 4 and 5, and probably apply to other segments as well. The one exception is the relation of length of sternite 5 without the apodemes (Table 10). The sternite of the haploid drone (4.966 mm) was shorter than those of the worker (4.979 mm) and queen (5.181 mm), the diploid drone having the longest sternite (5.235 mm). Thus the length of sternite 5 of diploid drones showed a super-female character, while that of sternite 4 showed a female character (Table 4).

Weight of drones

It is already known that the weight of a worker bee is about 100 mg, and that of a queen about 200 mg (e.g. Woyke, 1971). Table 13 shows that drones were heavier than females, and that diploid drones originating from all queens were heavier than haploids. In total, diploid drones were 36.1 mg or 16.0% heavier than haploids. The pure line diploid drones were on average 32.0 to 68.2 mg heavier than haploids (13.1 to 30.3%, average 23%). Thus weight of the diploid drone shows a super-male character.

Discussion and Conclusions

The results are summarized in Table 14. They show that out of twelve abdominal characters studied in haploid drones, four were larger, but as many as eight were smaller, than those found in at least one female caste. The segments of diploid drones were larger than those of haploids. Therefore the size of diploid segments was sometimes between those of the haploids and the females; sometimes they were in increasing-size sequence in the opposite direction to females. Thus diploid drone abdomen size varied in its relationship to those of haploids and females:

- (a) For the length of tergites and sternites 4 and 5 the sequence was W, Q, H, D: diploid drones thus showed super-male character. The weight of diploid drones showed the same character.
- (b) For the width of tergite and sternite with the front apodeme, the sequence in both segments was W, H, D, Q: diploid drones showed a caste character.
- (c) For the width of sternites 4 and 5 without the front apodeme, the sequence was H, D, W, Q: diploid drones showed an intersex character.
- (d) For the length of sternite 4 without the lateral apodemes, the sequence was H, W, D, Q: the diploid drone showed a female character.
- (e) For the length of sternite 5 without the lateral apodemes, the sequence was H, W, Q, D: the diploid drone showed a super-female character.

Without taking into account the measurements of the queens, the diploid drone body parts showing caste characters would be considered super-male. Out of twelve abdominal dimensions studied, four showed super-male character, four caste character, two intersex, one female, and one super-female character.

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