SIZE OF EGGS FROM QUEENS OF THREE ASIAN *Apis* SPECIES AND LAYING WORKERS OF *Apis cerana*

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Summary

The investigations were conducted in spring 1999 in Jugedi, Chitwan, Nepal, and in spring 1992 and 2000 in Bangkok, Thailand. The length and width of 722 eggs was measured. Of those, 279 eggs were from six *A. dorsata* queens, 150 eggs from three *A. cerana* queens, 150 eggs from two *A. cerana* colonies with laying workers, and 143 eggs from six *A. andreniformis* queens. The results showed that eggs from *A. dorsata* queens were on average, shorter than from the smaller *A. cerana* queens. Eggs from *A. dorsata* queens were on average also narrower than from the smaller *A. cerana* and *A. andreniformis* queens. The variation in the length and width was 2.0 and 1.3 times higher respectively in eggs from laying workers than from queens. A positive correlation was found between the width and length of eggs from queens and negative in eggs from laying workers. Thus, longer eggs from queens were also wider, while longer eggs from laying workers were narrower. The volume of eggs from the small *A. andreniformis* queens was on average 1.3 am 2.4 times higher than from the larger *A. cerana* and *A. dorsata* queens respectively. The volume of eggs from *A. cerana* laying workers was 1.7 times as high as from queens of the same species. No any relationship was detected between size of eggs and body size of queens and laying workers of different Apis species.

Keywords: Eggs, size of eggs, *A. dorsata*, *A. cerana*, *A. andreniformis*, laying workers, Nepal, Thailand.

INTRODUCTION

The size of thousands of eggs of *Apis mellifera* bees was measured (Hejtmanek 1961, Jordan 1961). Woyke (1975, 1993) measured the size of few eggs of three Asian honey bee species: *Apis dorsata*, *Apis cerana* and *Apis florea*. The sizes of eggs laid by queens and laying workers of *A. florea* (Woyke and Wongsiri 1992) and *A. mellifera* (Woyke 1994) were also compared. Surprisingly, eggs from *A. florea* laying workers were on average larger than from queens, and eggs from *A. mellifera* laying workers were on average shorter, but wider than from queens. The eggs change their size during the incubation period in the three Asian honey bees (Woyke 1975, 1993), as well as in the European honey bee *A. mellifera* (Woyke 1998).

The purpose of this investigation was to compare the size of higher number of eggs from three species of Asian honey bee queens, and laying workers from some colonies. We wanted also to find out the relationship between the size of eggs and body size of different species of queens and laying workers.

MATERIAL AND METHODS

The investigations were conducted in March and April 1999 in Dabur Apiculture

Centre in Jugedi, Chitwan, Nepal, and in March 1992 (two *A. andreniformis* colonies), and May 2000 in Department of Biology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand. Pieces of combs containing *A. dorsata* eggs were collected from three colonies (Nos 1, 2 and 3) in the Institute of Agriculture and Animal Science, Tribhuven University in Rampur, Nepal, and from three other colonies (Nos 4, 5, and 6) from Samut Songkram and Songkla Provinces, Thailand. Thirty to fifty eggs were collected from each *A. dorsata* colony.

A. cerana eggs were collected from colonies in Dabur apiary in Jugedi. Fifty eggs were collected from each of the three *A. cerana* colonies headed by queens, and 75 from each of the two colonies with laying workers.

A. andreniformis eggs were collected from two colonies (Nos 1 and 2) in Chantaburi, in 1992, (by J. Woyke) and from four other nests (Nos 3 - 6) in Chantaburi, Songkla, Ratchaburi, and Phuket Provinces in May, 2000. Twenty to thirty eggs were collected from each colony.

To assure the collection of eggs of different ages, they were collected from different places of both sides of the combs, some were collected from areas near already hatched larvae and other at the margin of egg area. The eggs were removed from comb cells with the aid of a needle. They were put down on a glass microscope slide. Egg length and width was measured under a stereomicroscope with the aid of an eye-piece micrometer (magnification 72 x). The length was measured as the distance between anterior and posterior poles of the chorion of egg. The width was measured in the middle of the length. In total, 1444 measurements of 722 eggs were made.

Shape index of eggs was calculated as the ratio of egg width to length. The volume of eggs was calculated as an ellipsoid. This way, the volume is a little underestimated. However, the data are valid for comparison purposes.

One-way analysis of variance as well as nested ANOVA was applied. Multiple comparison LS range tests was used to detect significant differences between the means. Correlation coefficients between length and width of eggs were also calculated.

RESULTS

1. Characteristics of the size of eggs from queens of different species and from laying workers

1.1. Eggs from *Apis dorsata* queens

The overall mean length of eggs from six *A. dorsata* queens was 1.67 mm (Table 1). Among 6 mean lengths of egg, 4 were found to differ significantly. Of the eggs from three queens in Thailand (Nos 4, 5 and 6), 2 mean lengths were within mean range of eggs from queens in Nepal. Queen No. 1 oviposited the longest eggs (mean 1.83 mm). The shortest eggs from that queen were as long as the longest from one queen (No. 5 in Thailand) and longer than the longest from four other queens. The coefficient of length variation in that queen was lower than in all other queens.

The overall mean width of eggs was 0,34 mm (Table 2). Eggs from queens in Thailand (Nos 4 - 6) were narrower than those from Nepal. It is interesting to note that the longest eggs (mean) from queen No. 1 (Table 1) were as wide as the shorter ones from queen No. 3 (Tables 1 and 2). Thus, the ratio of length to width of eggs must differ in different colonies.

The overall mean volume of eggs from *A. dorsata* queens was 0.104 mm^3 (Table 4). The mean volume of eggs from the three queens in Thailand did differ. Two of those means did not differ from the one of queen in Nepal.

Table 1

Length of eggs from *A. dorsata*, *A. cerana* and *A. andreniformis*

Number	No	Range mm	Mean ± SD mm	CV %
A. dorsata queens				
1	50	1.79 - 1.89	1.825 ± 0.032 i*	1.77
2	50	1.53 - 1.68	1.610 ± 0.039 cd	2.44
3	30	1.50 - 1.71	1.631 ± 0.042 de	2.51
4	50	1.40 - 1.68	1.559 ± 0.068 a	4.39
5	50	1.56 - 1.79	1.689 ± 0.051 fg	3.00
6	49	1.55 - 1.77	1.682 ± 0.048 fg	2.68
Overall	**279**	**1.40 - 1.89**	**1.668 ± 0.099** β**	**5.92**
A. cerana queens				
1	50	1.58 - 1.82	1.700 ± 0.064 g	3.74
2	50	1.76 - 1.92	1.834 ± 0.035 i	1.91
3	50	1.63 - 1.97	1.829 ± 0.065 i	3.57
Overall	**150**	**1.58 - 1.97**	**1.788 ± 0.083** γ	4.62
A. cerana laying workers				
1	75	1.45 - 1.95	1.739 ± 0.0101 h	5.80
2	75	1.16 - 1.87	1.597 ± 0.0165 bc	10.34
Overall	**150**	**1.16 - 1.95**	**1.668 ± 0.015** β	**9.22**
A. andreniformis queens				
1	25	1.50 - 1.60	1.561 ± 0.024 a	1.55
2	25	1.55 - 1.60	1.565 ± 0.0.22 ab	1.39
3	30	1.41- 1.75	1.565 ± 0.077 ab	4.94
4	23	1.55 - 1.83	1.691 ± 0.077 fg	4.58
5	20	1.58 - 1.73	1.656 ± 0.052 ef	3.16
6	20	1.51 - 1.65	1.584 ± 0.039 abc	2.45
Overall	**143**	**1.41 - 1.83**	**1.600 ± 0.074** α	4.62

* Different letters after SD indicate statistically significant differences between means $P < 0.05$.
** Greek letters concern overall means.

1.2. **Eggs from *Apis cerana* queens**

The overall mean length of eggs from three *A. cerana* queens was 1.79 mm (Table 1). Eggs from queen No. 1 were significantly shorter than from the two other queens. However, length ranges of eggs from all three queens overlapped. The coefficient of variation was the lowest in queen No. 2. Thus, considerable differences were found in different characteristics of the length of eggs from different queens.

The overall mean width of *A. cerana*

Table 2

Width of eggs from *A. dorsata*, *A. cerana* and *A. andreniformis*

Number	No	Range	Mean ± SD mm	CV %
A. dorsata queens				
1	50	0.36 - 0.42	0.388 ± 0.016 fg*	4.07
2	50	0.32 - 0.37	0.338 ± 0.014 c	4.28
3	30	0.37 - 0.40	0.386 ± 0.015 ef	3.94
4	50	0.27 - 0.39	0.325 ± 0.028 b	8.50
5	50	0.27 - 0.37	0.318 ± 0.027 b	8.38
6	49	0.22 - 0.44	0.307 ± 0.036 a	11.69
Overall	**279**	**0.22 - 0.44**	**0.341 ± 0.039** α**	**11.53**
A. cerana queens				
1	50	0.34 - 0.40	0.367 ± 0.015 d	4.27
2	50	0.37 - 0.42	0.402 ± 0.015 hi	3.80
3	50	0.37 - 0.42	0.394 ± 0.019 fgh	4.73
Overall	**150**	**0.34 - 0.42**	**0.388 ± 0.022** β	**5.75**
A. cerana laying workers				
1	75	0.37 - 0.50	0.434 ± 0.025 j	5.83
2	75	0.35 - 0.55	0.448 ± 0.038 k	8.46
Overall	**150**	**0.35 - 0.55**	**0.441 ± 0.033** γ	**7.46**
A. andreniformis queens				
1	25	0.35 - 0.40	0.375 ± 0.012 de	3.32
2	25	0.35 - 0.38	0.363 ± 0.011 d	2.99
3	30	0.37 - 0.43	0.397 ± 0.020 fgh	4.94
4	23	0.38 - 0.46	0.414 ± 0.023 l	5.44
5	20	0.38 - 0.43	0.400 ± 0.016 ghi	3.89
6	20	0.36 - 0.44	0.394 ± 0.017 fgh	4.31
Overall	**143**	**0.35 - 0.46**	**0.390 ± 0.024** β	**6.11**

* Different letters after SD indicate statistically significant differences between means $P < 0.05$.
** Greek letters concern overall means.

eggs was 0.39 mm (Table 2). Eggs from queen No. 1 were significantly the narrowest. It is worth to note that the narrowest eggs were also the shortest (Tables 1 and 2). The ranges of the width of eggs from all queens overlapped.

The mean volumes of eggs from all three queens differed significantly, although the lengths and widths did not (Tables 1, 2 and 3).

Table 3

Shape index (width to length ratio) and correlation between width and length of eggs from *A. dorsata*, *A. cerana* and *A. andreniformis*

Number	No	Shape index			Correlation	
		Range mm	Mean ± SD mm	CV %	r**	P
A. dorsata queens						
1	50	0.198 - 0.231	0.213 ± 0.008 bc*	3.76	0.38+	0.006
2	50	0.190 - 0.231	0.210 ± 0.008 b	3.99	0.40+	0.004
3	30	0.220 - 0.253	0.236 ± 0.010 de	4.08	0.23	0.219
4	50	0.172 - 0.264	0.209 ± 0.018 b	8.79	0.21	0.141
5	50	0.151 - 0.218	0.189 ± 0.016 a	8.57	0.09	0.544
6	49	0.128 - 0.240	0.182 ± 0.021 a	11.53	0.18	0.228
Overall	**279**	**0.128 - 0.264**	**0.204 ± 0.022** α	**10.65**	**0.40+**	**0.000**
A. cerana queens						
1	50	0.187 - 0.241	0.216 ± 0.012 bc	5.51	0.04	0.779
2	50	0.201 - 0.235	0.219 ± 0.007 c	3.36	0.47+	0.001
3	50	0.190 - 0.258	0.215 ± 0.012 bc	5.55	0.14	0.308
Overall	**150**	**0.187 - 0.258**	**0.217 ± 0.011** β	**4.93**	**0.57+**	**0.000**
A. cerana laying workers						
1	75	0.190 - 0.310	0.251 ± 0.021 gh	8.28	-0.03	0.296
2	75	0.217 - 0.426	0.285 ± 0.050 i	17.55	-0.42+	0.000
Overall	**150**	**0.190 - 0.426**	**0.268 ± 0.042** δ	**15.64**	**-0.37+**	**0.000**
A. andreniformis queens						
1	25	0.230 - 0.251	0.240 ± 0.007 def	2.86	0.54+	0.006
2	25	0.219 - 0.242	0.231 ± 0.006 d	2.76	0.29	0.160
3	30	0.225 - 0.287	0.254 ± 0.015 h	5.89	0.22	0.241
4	23	0.224 - 0.277	0.245 ± 0.012 efgh	4.81	0.55+	0.006
5	20	0.224 - 0.259	0.241 ± 0.010 defg	4.21	0.22	0.351
6	20	0.222 - 0.272	0.249 ± 0.013 efg	5.26	-0.10	0.668
Overall	**143**	**0.219 -0.287**	**0.243 ± 0.013** γ	**5.44**	**0.52+**	**0.000**

* Different letters after SD indicate statistically significant differences between means $P < 0.05$. Greek letters concern overall means.

** r - correlation coefficient between width and length of eggs.

\+ indicates statistically significant correlation $P < 0.05$.

Table 4

Volume of eggs from *A. dorsata*, *A. cerana* and *A. andreniformis*

Number	No	Range mm^3	Mean ± SD mm^3	CV %
A. dorsata queens				
1	50	0.122 - 0.168	0.144 ± 0.013 c	8.92
2	50	0.082 - 0.121	0.097 ± 0.010 b	9.93
3	30	0.108 - 0.143	0.128 ± 0.011 c	8.81
4	50	0.058 - 0.119	0.087 ± 0.016 ab	18.25
5	50	0.061 - 0.126	0.090 ± 0.016 ab	17.34
6	49	0.044 - 0.140	0.080 ± 0.020 a	23.90
Overall	**279**	**0.435 - 0168**	**0.104 ± 0.027** α	**26.10**
A. cerana queens				
1	50	0.099 - 0.141	0.120 ± 0.011 c	9.38
2	50	0.126 - 0.177	0.156 ± 0.013 e	8.55
3	50	0.234 - 0.333	0.284 ± 0.030 i	10.52
Overall	**150**	**0.099 - 0.333**	**0.187 ± 0.73** β	**39.25**
A. cerana laying workers				
1	75	0.240 - 0.448	0.329 ± 0.042 j	12.92
2	75	0.190 - 0.428	0.321 ± 0.049 j	15.16
Overall	**150**	**0.190 - 0.448**	**0.325 ± 0.046** δ	**14.06**
A. andreniformis queens				
1	25	0.184 - 0.248	0.219 ± 0.017 f	7.59
2	25	0.190 - 0.225	0.206 ± 0.013 f	6.50
3	30	0.199- 0.311	0.248 ± 0.029 g	11.89
4	23	0.228 - 0.377	0.291 ± 0.041 i	13.91
5	20	0.228 - 0.314	0.265 ± 0.024 h	9.00
6	20	0.203 - 0.314	0.246 ± 0.022 g	8.89
Overall	**143**	**0.183 - 0.377**	**0.245 ± 0.38** γ	**15.51**

* Different letters after SD indicate statistically significant differences between means P < 0.05.
** Greek letters concern overall means.

1.3. Eggs from *Apis cerana* laying workers

The overall mean length of eggs from *A. cerana* laying workers in 2 colonies was 1.67 mm (Table 1). The mean length of eggs from both colonies differed significantly. However, the length ranges, overlapped (Fig. 1). The coefficients of variations were very high.

Table 5

Nested analysis of variance of size of 722 eggs from 17 colonies in four groups (queens in 3 species and laying workers)

		Length			Width		
Source	DF	M SS*	F	P	M SS	F	P
Total	721						
4 groups	3	0.911478	3.175	>0.05	0.335966	12.500	<0.01
17 colonies within groups	13	0.287066	47.131	<0.01	0.026876	47.780	<0.01
Error	705	0.006091			0.000563		
		Shape Index			Volume		
Source	DF	M SS	F	P	M SS	F	P
Total	721						
4 groups	3	0.149856	15.573	< 0.01	1.739150	22.632	<0.01
17 colonies within groups	13	0.009623	21830	<0.01	0.076844	104.295	<0.01
Error	705	0.000441			0.000737		

* mean square

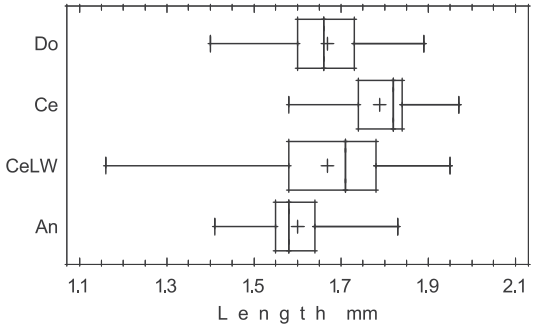

Fig. 1. Distribution of 0, 25, 50, 75 and 100 percentile of length of eggs from *A. dorsata* queens (Do), *A. cerana* queens (Ce), *A. cerana* laying workers (CeLW), and *A. andreniformis* queens (An). - median, + mean.

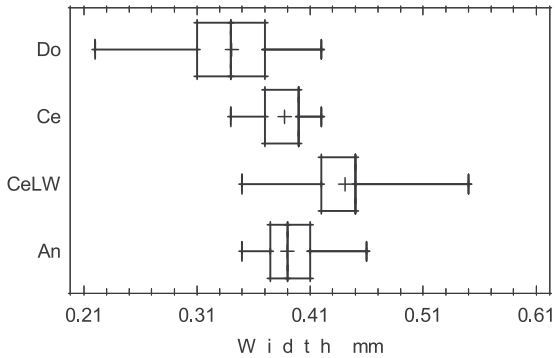

Fig. 2. Distribution of 0, 25, 50, 75 and 100 percentile of width of eggs from *A. dorsata* queens (Do), *A. cerana* queens (Ce), *A. cerana* laying workers (CeLW), and *A. andreniformis* queens (An).

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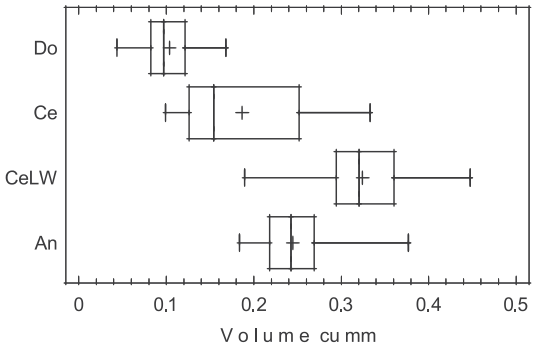

Fig. 3. Distribution of 0, 25, 50, 75 and 100 percentile of volume of eggs from *A. dorsata* queens (Do), *A. cerana* queens (Ce), *A. cerana* laying workers (CeLW), and *A. andreniformis* queens (An).

The overall width of eggs was 0.44 mm. The mean widths of eggs from both colonies differed significantly. However, the width range of eggs from colony No. 1, was within that of eggs from colony No. 2. This differs from the relationship of egg lengths. The longer eggs from colony No. 1 were narrower than the shorter ones from colony No. 2 (Tables 1 and 2). Thus, reverse relationship between width and length was found in eggs from laying workers than from queens.

The mean volumes of eggs from both colonies did not differ significantly (Table 4), although the lengths and widths differed.

1.4. Eggs from *Apis andreniformis* queens

The overall mean length of eggs from 6 *A. andreniformis* queens was 1.60 mm (Table 1). Mean lengths of eggs from four queens were not found to differ significantly. The two other means did not differed significantly from each other. Both, the range, and the variation of length of eggs from two queens (Nos 3 and 4) were higher than those in eggs from the other queens.

The overall mean width of eggs was 0.39 mm (Table 2). Mean widths of eggs from three queens were not found to differ significantly. The three other means differed significantly from each other. The shortest eggs from queen No. 1 were also among the narrowest, and the longest ones from queen No. 4 were also the widest (Tables 1 and 2).

The mean volumes of eggs from two queens did not differ significantly. Thus, the relationship between the mean lengths and widths of eggs from different queens differed from the volume relationships of eggs from the same queens (Tables 1, 2 and 4).

2. Comparison of the size of eggs in different *Apis* species

Nested analysis of variance divided the variance into two components; contributed by the four groups (queens in the three species and laying workers) and by the colonies within the groups (Table 5). No significant differences were found between the four length groups. However, highly significant differences were found between mean lengths of eggs from different colonies within the groups. Highly significant differences were also found between mean sizes of the other characters: width, shape index and volume for both, the groups as well as colonies within the groups. However, to compare the overall mean sizes as well as the means of eggs from particular colonies between different groups we were interested in the total variance due to groups and colonies. Therefore one-way ANOVA

was applied to detect significant differences between means presented below in Tables 1-4.

2.1. **Length of eggs from queens**

The overall mean lengths of eggs from queens of all three species: *A. dorsata*, *A. cerana* and *A. andreniformis* differed significantly (Table 1). Eggs from *A. cerana* queens were the longest, and from *A. andreniformis* the shortest. Fig. 1. shows that the 25% to 75% interquartile length ranges of eggs from the large *A. dorsata* queens and the small *A. andreniformis* queens overlapped. The 25% quartile length of eggs from *A. cerana* queens (1.74 mm) was higher than the 75% quartile ranges of eggs from *A. dorsata* (1.73 mm) and *A. andreniformis* queens (1.64 mm). It is interesting to note that eggs from the smaller *A. cerana* queens were on average significantly longer than from the larger *A. dorsata* queens.

However, variation occurred in the mean lengths of eggs originating from particular queens of different Apis species. Among the group of the lower overall mean length of eggs from *A. dorsata* queens, the mean for the length of eggs from *A. dorsata* queen No. 1 was significantly higher than that of eggs from *A. cerana* queen No. 1, and as high as the mean for lengths of eggs from two other *A. cerana* queens (Nos 2 and 3).

Although, the overall mean for length of eggs from *A. andreniformis* queens was significantly the lowest, the means for the length of eggs from all six queens were significantly lower only from one *A. dorsata* queen (No. 1). Even the lowest mean for length of eggs from *A. andreniformis* queen No. 1 did not differ significantly from the mean length of eggs from *A. dorsata* queen No. 4. Mean length of eggs from *A. andreniformis* queen No. 4 did not differ significantly even from that of eggs from *A. cerana* queen No. 1, within the highest group overall mean.

Thus, although the overall mean lengths of eggs from queens of the three species differed significantly, mean lengths of eggs from particular queens of one species were similar to those in the two other species.

2.2. **Length of eggs from laying workers and queens**

The overall mean for length of eggs from *A. cerana* laying workers was significantly lower than that of eggs from *A. cerana* queens. However, the 25% to 75% interquartile ranges of length of eggs from laying workers and queens overlapped (Fig. 1). The mean for length of eggs from laying workers in colony No. 1 was significantly higher than that of eggs from *A. cerana* queen No. 1. Thus, the smaller laying workers in one colony oviposited longer eggs than one of the queens.

The overall mean length of eggs from *A. cerana* laying workers and *A. dorsata* queens did not differ significantly. However, the mean for the length of eggs from *A. cerana* laying workers in colony No. 1 was significantly higher than that of eggs from two *A. dorsata* queens (Nos 5 and 6). Also the mean for the length of eggs from laying workers in colony No. 2 was similar to that of eggs from one *A. dorsata* queen (No. 2), and significantly higher than that of eggs from one *A. dorsata* queen (No. 4). Thus the small *A. cerana* laying workers oviposited eggs similar or longer than some *A. dorsata* queens. Hence, despite *A. cerana* laying workers were smaller than *A. cerana* and *A. dorsata* queens, the means for length of eggs from *A. cerana* laying workers were similar or higher than those of eggs from some queens of both species.

The overall mean for the length of eggs from *A. cerana* laying workers was significantly higher than that of eggs from *A. andreniformis* queens. However, the mean for length of eggs from laying workers in colony No. 2 was significantly lower

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than that of eggs from two *A. andreniformis* queens (Nos 4 and 5), and did not differ significantly from that of eggs from 3 others *A. andreniformis* queens (Nos 2, 3 and 6).

Fig. 1. shows that both, the ranges of length as well as the 25% to 75% interquartile ranges of eggs from laying workers and queens of the three species overlapped.

2.3. Width of eggs from queens

The overall mean for the width of eggs from *A. dorsata* queens was significantly lower than those for eggs from *A. cerana* and *A. andreniformis* queens (Table 2). The two last means did not differ significantly. The 75% quartile width of egg from *A. dorsata* queens (0.37 mm) was as low as the 25% quartiles of eggs from *A. cerana* and *A. andreniformis* queens (Fig. 2). The 25% to 75% interquartile ranges of eggs from *A. cerana* and *A. andreniformis* overlapped. Thus, eggs from *A. dorsata* queens were the narrowest. It is interesting to note that eggs from *A. cerana* and *A. andreniformis* queens were on average wider than from the larger *A. dorsata* queens.

However, variation occurred in mean widths of eggs from particular queens of different Apis species. Among both groups of eggs of the higher overall means; (*A. cerana* and *A. andreniformis*), means for width of eggs lower than in *A. dorsata* group were found. Mean for the width of eggs from one *A. cerana* queen (No. 1) was significantly lower than that for eggs from two *A. dorsata* queens (Nos 1 and 3). Similarly, means for the width of eggs from two *A. andreniformis* queens (Nos 1 and 2) were significantly lower than that for eggs from one *A. dorsata* queen (No. 1), and eggs from three *A. andreniformis* queens (Nos 3, 5 and 6) were as wide as eggs from two *A. dorsata* queens (Nos 1 and 3). On the other hand, mean for the width of eggs from only one *A. andreniformis* queen (No. 4) was significantly higher than that for eggs from all *A. dorsata* queens.

2.4. Width of eggs from laying workers and queens

The overall mean for the width of eggs from *A. cerana* laying workers was significantly higher than that of eggs from *A. cerana* queens (Table 2). The means for the width of eggs from laying workers in both colonies were significantly higher than those for eggs from any *A. cerana* queen. Both mean widths of eggs from *A. cerana* laying workers were also significantly wider than those of eggs from queens of any *Apis* species. The 25% quartile width range of all eggs from laying workers (0.42 mm) was higher than the 75% quartiles of eggs from queens of all three species (Fig. 2). Thus, eggs from laying workers were the widest. It is worth to note, that eggs from the large *A. dorsata* queens were the narrowest, and from the small *A. cerana* laying workers the widest.

2.5. Shape index of eggs from queens

Table 3 shows that the four overall mean shape indexes of eggs (width : length) differed significantly. The overall mean shape index (OMSI) of eggs from *A. dorsata* queens was the lowest, and that of eggs from *A. andreniformis* the highest. The overall mean width of eggs from *A. dorsata*, *A. cerana* and *A. andreniformis* queens was 0.204, 0.217 and 0.243 times of its length, respectively. Thus, the eggs were 4.9, 4.6 and 4.1 times longer then wider, respectively. Hence, eggs from *A. dorsata* queens were proportionally the narrowest and from *A. andreniformis* queens proportionally the widest. However, eggs from some *A. dorsata* queens were similar or significantly proportionally wider than those from queens of both other species.

2.6. Shape index of eggs from laying workers and from queens

The overall mean shape index of eggs from *A. cerana* laying workers was significantly higher than that of eggs from queens of the same species (Table 3). Eggs from laying workers in both colonies were on average proportionally significantly wider than those from any *A. cerana* queen. The overall mean shape index of eggs from laying workers was also significantly higher than those of eggs from queens of the two other species. Thus, eggs from laying workers were proportionally the widest. They were on average 3.8 times as long as width (length : width).

However, variation occurred in shape indexes of eggs from particular queens. Mean shape indexes of eggs from *A. cerana* laying workers in both colonies were significantly higher than those of eggs from any *A. dorsata* queen. However, mean shape index of eggs from laying workers in colony No. 1 was similar to that of eggs from three *A. andreniformis* queens (Nos 4, 5 and 6), in the queen group of the highest OMSI. Mean shape index of eggs from laying workers in colony No. 2 (0.285) was the highest of all. These eggs were on average only 3.6 times as long as width.

The overall coefficient of variation for shape index of egg from laying workers was 3.2 times higher than that for eggs from *A. cerana* queens and 1.5 and 2.9 times higher than that for eggs from *A. dorsata* and *A. andreniformis* queens, respectively. Thus, the shape variation was higher for eggs from laying workers than from queens.

2.7. Correlation between width and length of eggs

The overall correlation coefficient between width and length was found positive and statistically significant for eggs from queens of all three *Apis* species (Table 3). Thus, longer eggs were also wider. However, correlation coefficients for eggs from particular queens, although positive, not always were found significant. Of correlation coefficients for eggs from 14 queens of the three species 5 (36%) were statistically significant.

The overall correlation coefficient for eggs from laying workers was negative and statistically significant. Thus, longer eggs were narrower. However, although correlation coefficients for eggs from both colonies were negative, only one (of two) was found significant.

2.8. Volume of eggs from queens

The overall volume of eggs from the large *A. dorsata* queens was significantly the smallest and that of the small *A. andreniformis* queens the largest (Table 4). It is interesting to note that eggs from the smallest queens were the largest. The overall volume of eggs from *A. andreniformis* queens was 1.3 ad 2.4 times as large as that from *A. cerana* and *A. dorsata* queens respectively. Eggs from *A. cerana* queens were on average 1.8 times as large as those from the larger *A. dorsata* queens. Variation occurred in mean volumes of eggs from particular queens. The mean volume of eggs from *A. cerana* queen No. 3 in the lower overall mean group was within the means of eggs from queens in the highest overall group of *A. andreniformis*. However, mean volumes of eggs from all *A. andreniformis* queens were significantly larger than from any *A. dorsata* queen. Moreover, the smallest particular *A. andreniformis* eggs were larger than the largest *A. dorsata* eggs.

2.9. Volume of eggs from laying workers and queens

The overall volume of eggs from *A. cerana* laying workers was significantly larger than that of eggs from queens of the same species (Table 4). The eggs from laying workers were 1.7 times larger than from queens. The overall volume of eggs from

laying workers was also significantly larger than that of eggs from queens of the two other species. Fig. 3 shows that the lower quartile of the volume of eggs from laying workers (0.29 mm^3) was higher than the higher quartile of eggs from queens of the same species (0.25 mm^3) as well as from queens of the two other species. The mean volumes of eggs from particular colonies with laying workers were significantly larger than those of eggs from any queen of the same species as well as from any queen of the two other species. However, particular eggs of the same volume as in *A. cerana* laying workers could be found within the ranges of eggs from *A. cerana* and *A. andreniformis* queens. But, the smallest eggs from *A. cerana* laying workers were larger then the largest from *A. dorsata* queens.

2.10. Variation of the dimensions of eggs from laying workers and queens

The most striking phenomenon was the much higher variation in the length and width of eggs from *A. cerana* laying workers than from queens (Tables 1 and 2). The overall coefficient variation for the length and the width was 2.0 and 1.3 times higher respectively for the of egg from laying workers than from queens. The overall range of egg length (0.79 mm) was 2.0 times higher and of width (0.20 mm) 2.5 time higher in laying workers than in queens (0.39 mm 0.08 mm), respectively. The 25% to 75% interquartile length range for eggs from laying workers (0.20 mm) was 2.0 times higher than of eggs from queens (0.10 mm, Fig. 1). However, the 25% to 75% interquartile width range, although higher in laying workers (0.42 - 0.45 mm) than in queens (0.35 - 0.42 mm) was similarly long (0,03 mm).

However, the overall coefficient for the variation of egg volume was 2.8 times higher for eggs from *A. cerana* queens (39.25%) than from laying workers (14.06%, Table 4). Similarly, the overall coefficients for the volume variation were higher for eggs from queens of the two other species, than for eggs from *A. cerana* laying workers. The 25% to 75% of the interquartile volume range for eggs from *A. cerana* queens (0.235 mm^3) was 1.91 times higher than that for eggs from laying workers (0.066 mm^3, Fig. 3).

Thus, the variation of egg length and width was higher in laying workers than in queens. However, variation of egg volume was higher in queens than in laying workers.

2.11. Relation between size of eggs and of body size of queens and laying workers

Of the honey bee species investigated, *A. dorsata* queens are the largest and *A. andreniformis* the smallest. *A. cerana* laying workers are smaller than queens of this species. The overall means of length, width, shape index and volume of eggs (Tables 1- 4) do not show relationships in this same order. The overall widths and volumes of eggs show rather reverse order to body sizes of the queens and laying workers. Thus, there is not any relation between the size of eggs and of body size of queens and laying workers.

DISCUSSION

Woyke (1993, 1998) showed that eggs change their size during the incubation period. The age of eggs investigated here is not known. Since the eggs were collected from different parts of the combs, it is likely that the average size of eggs during the incubation period is presented here. The eggs presented here were probably a little larger shortly after they have been oviposited.

Eggs from *A. cerana* laying workers were collected from only two colonies. However, number of eggs collected from each colony was increased to 75. It is

generally known, that not one but several laying workers oviposit eggs in a colony. They have different fathers. Thus, origin of eggs from two colonies with laying workers may be equal to origin of eggs from several queens.

All the means for lengths and widths of *A. dorsata* eggs presented here are a little lower than those presented by Woyke (1975 and 1993). However, the mean widths of eggs investigated earlier are within the ranges of width of eggs from particular queens presented here. Thus, some dimensions of *A. dorsata* eggs presented here and earlier overlap.

Some of the mean lengths and widths of *A. cerana* eggs presented here are within those presented by Woyke (1975 and 1993). However due to scarce material (1 *A. cerana* queen and 18 *A. dorsata* eggs) no statistical comparison was conducted. Now, we proved statistically the very interesting phenomenon that the smaller *A. cerana* and *A. andreniformis* queens oviposit on average larger (volume) eggs than the larger *A. dorsata* queens.

Eggs from *A. cerana* laying workers were shorter, but wider than from queens of the same species. Similar phenomenon was found for eggs from *A. mellifera* (Woyke 1994). However, eggs from *A. florea* laying workers were longer and wider then from queens (Woyke and Wongsiri 1992).

The most striking phenomenon was the much higher variation of the length and width of eggs from laying workers than from queens. Similar phenomenon was found for eggs from *A. florea* (Woyke and Wongsiri 1992) and from *A. mellifera* (Woyke 1994). One of the reasons may be due to the fact that the eggs were deposited not by one but by several laying workers in each colony. Similarly, the overall length and width variations of eggs from several queens were higher, than those of eggs deposited by individual queens. We suggest that the higher variation in the length and width of eggs deposited by laying workers compared to queens is characteristic for all honey bee species.

Although, the variation of length and width was higher in eggs from laying workers than from queens, the volume variation was higher in eggs from queens than from laying workers. This can be explained by the positive correlation between length and width in eggs from queens and negative in eggs from laying workers. Longer eggs from queens are also wider. However, longer eggs from laying workers are shorter. Thus, after multiplying length by width, the variation of volume increases in eggs from queens and decreases in eggs from laying workers.

Of the honey bee species investigated, *A. dorsata* queens were the largest and *A. andreniformis* the smallest. *A. cerana* laying workers were smaller than *A. cerana* queens. However, eggs from *A. cerana* queens were longer than from the largest *A. dorsata* queens.

The volume of eggs from the smallest *A. andreniformis* queens was larger than from the largest *A. dorsata* queens. Eggs from laying workers were larger than from queens of any species. Thus, no any relationship exists between the body size of the bees and the size of eggs produced by them. Sometimes, the relationship between the size of bees and of egg is reverse.

CONCLUSIONS

1. Of the three species, *A. dorsata*, *A. cerana* and *A. andreniformis*, eggs from *A. andreniformis* queens were on average the shortest and from *A. cerana* queens the longest. The smaller *A. cerana* queens oviposited on average longer eggs than the larger *A. dorsata* queens. However, similar mean lengths of eggs from particular queens could be found among all three honey bee species.
2. Eggs from *A. dorsata* queens were on

average narrower than from *A. cerana* and *A. andreniformis*. Thus the largest *A. dorsata* queens oviposited on average narrower eggs than the smallest *A. andreniformis* queens. However, similar mean widths of eggs from particular queens could be found among all three species.

3. Eggs from *A. cerana* laying workers were on average shorter than eggs from *A. cerana* queens. However, mean lengths similar to those of eggs from laying workers could be found within mean lengths of eggs from queens of all three species.
4. Eggs from *A. cerana* laying workers were on the average wider, than from queens of all three *Apis* species.
5. The variation in the length and width was 2.0 and 1.3 times higher respectively in eggs from laying workers than from queens.
6. A positive correlation between width and length was found for eggs from queens.
7. A negative correlation between width and length was found for eggs from laying workers.
8. The average volume of eggs from *A. dorsata* queens was significantly the smallest and that of *A. andreniformis* queens the largest. Eggs from *A. andreniformis* queens were on average 1.3 and 2.4 times as large as from *A. cerana* and *A. dorsata* queens, respectively. The volume of eggs from *A. cerana* laying workers was on average 1.7 times as large as from queens of the same species.
9. No any relationship exists between size of eggs and body size of queens and laying workers of the three *Apis* species

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WIELKOŚĆ JAJ OD MATEK TRZECH AZJATYCKICH GATUNKÓW RODZAJU *Apis*, ORAZ OD TRUTÓWEK *Apis **cerana***

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S t r e s z c z e n i e

Badania prowadzono wiosną 1999 roku w Jugedi, w prowincji Chitwan w Nepalu, oraz wiosną 1992 i 2000 r w Bangkoku w Tajlandii. Razem zmierzono długość i szerokość 722 jaj. Spośród nich 279 jaj od sześciu matek *A. dorsata*, 150 jaj od trzech matek *A. cerana* i 150 od trutówek z dwu gniazd *A. cerana*, oraz 143 jaj od sześciu matek *A. andreniformis*.

Uzyskane wyniki wykazały, że średnie długości jaja od matek *A. dorsata* były mniejsze niż od mniejszych matek *A. cerana*. Średnie szerokości jaj od matek *A. dorsata* były również mniejsze niż od mniejszych matek *A. cerana* i *A. andreniformis*. Jaja od trutówek *A. cerana* były średnio grubsze niż od matek wszystkich trzech gatunków. Zmienność długości i szerokości jaj od trutówek była odpowiednio 2.0 i 1.3 razy większa niż jaj od matek tego samego gatunku. Pozytywną korelację między szerokością a długością stwierdzono dla jaj od matek. Negatywną korelację stwierdzono dla jaj od trutówek. Tak więc, dłuższe jaja od matek były również grubsze, natomiast dłuższe jaja od trutówek były węższe. Jaja od małych matek *A. andreniformis* były w porównaniu do jaj od większych matek *A. cerana* i A. dorsata odpowiednio średnio 1.3 i 2.4 razy większe. Objętość jaj od trutówek *A. cerana* była średnio 1.7 razy większa niż od matek tego samego gatunku. Nie wykryto związku między wielkością jaj, a wielkością ciała matek i trutówek różnych gatunków pszczół.

Słowa kluczowe: jaja, wielkość jaj, *Apis dorsata*, *Apis cerana*, *A. andreniformis*, trutówki, Nepal, Tajlandia.