

Abdomen flipping of *Apis dorsata breviligula* worker bees correlated with temperature of nest curtain surface*

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Abstract – *Apis laboriosa* and *Apis dorsata* worker bees in the curtain covering the nest comb perform dorso-ventral abdomen flipping (AF). Relationship between percentage of bees performing AF and the nest surface temperature (t_c) or ambient temperature (t_a) was investigated on *A. dorsata breviligula* nests in the Philippines. When both temperatures dropped down the %AF increased. Partial correlation showed, that the correlations between %AF and t_c were about 4 times higher than between %AF and t_a . This support the hypothesis that worker bees of the mantle of the curtain, which perform AF, react rather to the temperature around them in the surface of the curtain than to ambient temperature some distance apart.

Apis dorsata / abdomen flipping / nest curtain / temperature correlation / Philippines

1. INTRODUCTION

Apis laboriosa Smith and *Apis dorsata* Fabr. worker bees in the curtain covering the nest comb perform dorso-ventral abdomen flipping (AF). Some colonies perform AF throughout each day. The high rates of performance of those movements suggest that they play an important role in the life of the colonies. Woyke et al. (2004) suggested that AF of workers of the mantle of the curtain might provide a signal for the bees inside the nest, indicating the need for heating. They suggested also that many contractions of muscles raising the abdomen might produce some heat. Woyke et al. (2004) found that the percentage of workers performing AF increased when ambient temperature (t_a) decreased. However, in some cases, the intensity of AF changed although t_a did not. Therefore, in the present investigation we tested the suggestion of Woyke et al. (2004) that the intensity of AF is more closely correlated with the temperature of the

surface of the curtain (t_c) rather than with t_a . As far we know, the temperature of the mantle of *A. dorsata* nest curtains has not been examined.

2. MATERIALS AND METHODS

Two nests of *A. dorsata breviligula* Maa were observed, one 1 March 2004 in Los Baños (alt. 50 m), and the other from 4–6 March in Alfonso (alt. 600 m), the Philippines. The activities of worker bees on the surface of the nest curtains were recorded with a video camera recorder from a distance of 1 m. The records were made during 3 min, mostly when t_a changed by 1 °C. All together, 21 records were made. On the screen, 5 rows of worker with 12 bees in each row (altogether 60) were visible. Worker bees performing AF during 3 s were counted on a TV screen. The ratio of this number, to the total number of bees visible on the screen, gave the % of bees performing AF. The counts were repeated 10 times, giving a total of 210 observations. Within the 1260 bees examined, 508 AF of worker bees were recorded. Ambient temperature (t_a) was recorded with electronic thermometer placed in shade 1 m above ground near

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the nest. Also the temperature of the outer layer of bees of the nest curtain was measured with the aid of an external thermocouple inserted between those bees. Proportions were arcsine transformed prior to statistical analysis.

3. RESULTS

Figure 1 shows that t_c was not constant. In Los Baños, when t_a was 35 °C or higher then t_c was lower than t_a . However, when t_a was 34 °C or lower, then t_c was higher than t_a . In Alfonso, t_a was below 29 °C during all 3 days of observation. In this condition, t_c was always higher than t_a .

When t_a decreased in both study sites by 17 °C, (from 37 °C to 20 °C), then t_c decreased only by 9.4 °C (from 35.4 °C to 26 °C). Thus, the variation was lower in t_c than in t_a .

Paired t-tests showed that in Los Baños at high t_a ($\bar{X} = 33.5$ °C) no significant difference was found between t_c (34.5 °C) and t_a ($t = 0.57$, $P = 0.58$). However, in Alfonso at lower t_a ($\bar{X} = 24.0$ °C), the three daily means of t_c ($\bar{X} = 28.2$ to 28.9 °C) were highly significantly higher than t_a ($t = 9.68$ – 12.97 , all $P < 0.0003$).

The correlation between t_a and t_c in Los Baños at high t_a ($r = 0.95$, $P < 0.0001$) was slightly lower than in Alfonso at lower t_a (all 3 $r = 0.99$, $P < 0.0001$). Nevertheless, changes at t_c in both conditions, were highly and significantly correlated with changes in t_a . Both, the significant difference between t_c and t_a at lower t_a , as well as the high correlation between them, shows that the value of t_c was the result of the interaction of the high brood nest temperature ($\bar{X} = 31$ – 33 °C) and the lower t_a .

AF of curtain workers was not observed at ambient temperatures above 30 °C in Los Baños, when no significant difference was found between t_a and t_c . However, AF were recorded at t_a below 29 °C in Alfonso when significant differences were found between t_a and t_c . When t_a decreased from 28 to 20 °C and t_c from 30.7 to 26 °C the percentage of workers performing AF increased significantly from 1.7% to 14.8% (Fig. 1).

During all 3 days in Alfonso, high correlations were found between %AF and both t_a and t_c (Tab. I). The correlations were little higher between %AF and t_c , than between

%AF and t_a . The R-Squared statistics were in the tree days little higher for %AF and t_c , than for %AF and t_a . This suggested that the R-Squared statistics for t_c , explained the %AF variability better than the R statistics for t_a .

To get a clearer indication which of the independent variables the t_a or the t_c has the greatest effect on the dependent %AF variable, additional calculations were made. Partial correlation showed, that the correlations were in particular days 3.3–4.8 times ($\bar{X} = 3.9$) higher between %AF and t_c than between %AF and t_a (Tab. I). The P-values for r of %AF and t_c presented only a fraction of 0.2–0.4 of those values for t_a . This indicates higher confidence level for t_c than t_a correlations. Partial correlation was also calculated for all the data from the tree days pulled together, taking into account the day variable as well. The correlation between %AF and t_c : $r = -0.445$, $P = 0.028$, $df = 17$, $N = 21$, was statistically significant and was 3.0 times stronger than between %AF and t_a : $r = -0.149$, $P = 0.271$, which was not significant.

Multiple regressions analysis was also calculated for the dependent %AF variable and both independent variables, the t_a and t_c . The multiple regression model to describe the relationship between the three variables was; %AF = 70.56 – 1.88 t_c – 0.48 t_a . The multiple regression analysis showed that the P-values for the relationship between %AF and t_c variables presented only a fraction of 0.2 to 0.4 of the values for %AF and t_a (Tab. I.) This indicates higher confidence level for t_c then for t_a .

Since the highest P-values belonged to t_a , the Stat Advisor of the statistical program Statgraphics 4.1 suggested, to consider removing the t_a variable from the model, to simplify it.

4. DISCUSSION

Partial correlation showed that the percentage of bees performing AF was about 4 times stronger correlated with t_c then with t_a . The P-values for correlations between %AF and t_c presented only a fraction of 0.3 of P-values for %AF and t_a . Similarly, multiple regression analysis showed that P-values for relationship between %AF and t_c variable presented also

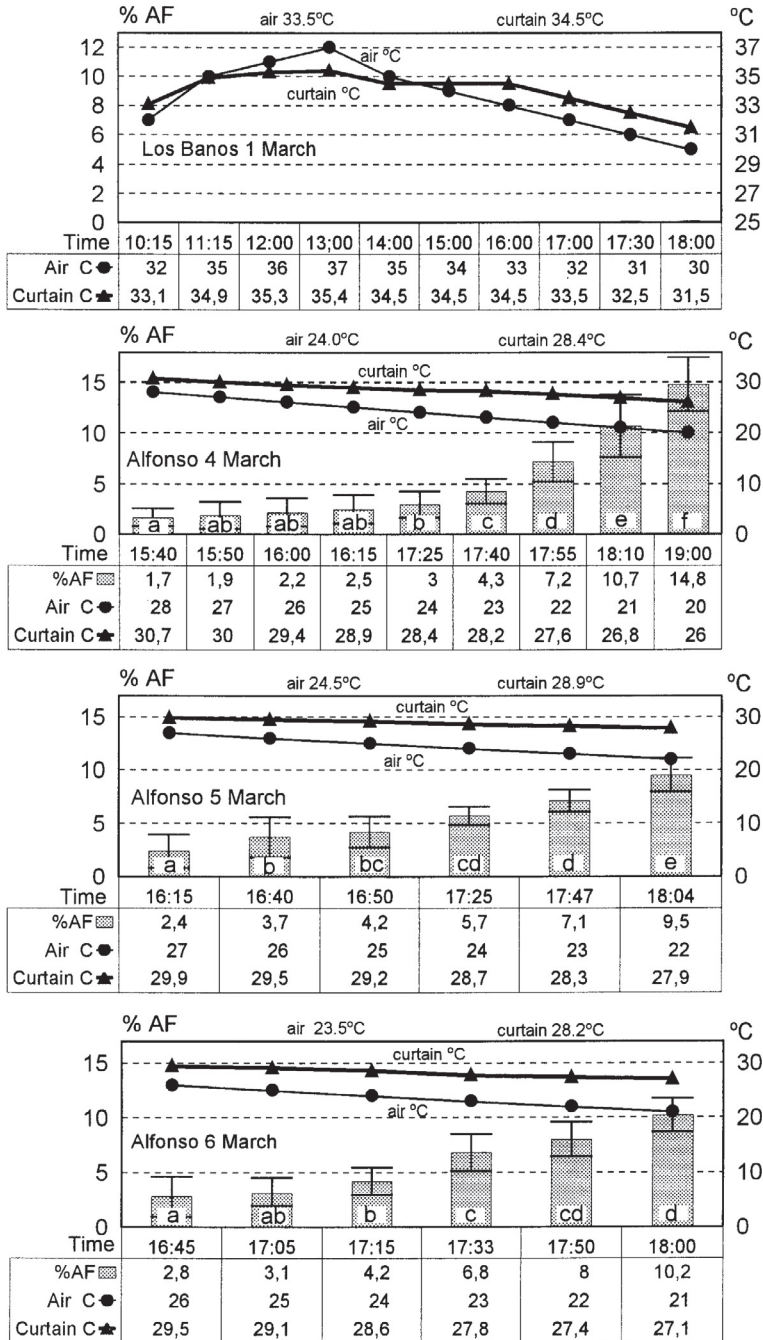


Figure 1. Percentage of worker bees performing abdomen flipping (AF) in relation to air and curtain surface temperatures. Bars – means of 10 repetitions. Different letters at the bottom of the bars indicate significant differences between means. Error vectors present SD. Data above the upper frame lines indicate daily mean air and curtain temperatures.

Table I. Relationship between percentages of performing abdomen flipping (%AF) and both temperatures: ambient (t_a) and surface of nest curtain (t_c). Correlation: r simple, or r partial and multiple regression analysis.

	4 March		5 March		6 March	
	r	P^*	r	P	r	P
r simple						
t_a	-0.930	0.000	-0.992	0.000	-0.985	0.000
t_c	-0.941	0.000	-0.994	0.000	-0.992	0.000
R-squared % t_a	86.4		98.4		96.9	
R-squared % t_c	88.6		98.9		98.4	
r partial						
t_a	-0.126	0.383	-0.191	0.379	-0.150	0.405
t_c	-0.421	0.149	-0.578	0.154	-0.715	0.087
t_c/t_a	3.3	0.4	3.7	0.4	4.8	0.2
mult. regression	t-stat.		t-stat.		t-stat.	
t_a	0.312	0.766	0.336	0.759	0.263	0.810
t_c	-1.137	0.299	-1.227	0.307	-1.770	0.175
t_c/t_a		0.4		0.4		0.2

$P = P$ -value of statistical significance.

only a fraction of 0.3 of P for relationship between %AF and t_a . Thus, both types of P -values indicated higher confidence level for t_c than for t_a . Hence, statistical calculations indicate that the curtain temperature has greater effect on the percentage of bees performing AF than air temperature has. This support the suggestion of Woyke et al. (2004) that t_c is related with %AF closer and explains the variability in %AF better than t_a does.

Certainly, worker bees of the mantle of the curtain, which perform AF, react rather to the temperature around them in the surface of the curtain than to ambient temperature some distance apart.

Résumé – Corrélation du battement de l'abdomen des ouvrières d'*Apis dorsata breviligula* avec la température à la surface du rideau d'abeilles. Les ouvrières d'*Apis laboriosa* et *Apis dorsata* présentes dans le rideau qui couvre le rayon du nid exécutent un battement dorso-ventral de l'abdomen (AF), qui semble jouer un rôle important dans la vie des colonies. Ce pourrait par exemple être un signal pour les abeilles à l'intérieur du nid leur indiquant le besoin de chauffer. Nous avons étudié si la température ambiante (t_a) ou la température de la surface du nid (t_c) était corrélée au pourcentage d'abeilles qui exécutaient un battement de l'abdomen (%AF). Deux nids d'*A. dorsata breviligula* ont été observés du 1^{er} au 6 mars 2004 dans la région de Los Baños, Philippines. L'activité des abeilles à la surface du rideau t_a a été enregistrée

avec une caméra vidéo à 1 m de distance et les températures t_a et t_c avec un thermomètre électronique. Parmi les 210 enregistrements, 1260 abeilles ont été examinées, dont 508 exécutaient un AF. La figure 1 montre que lorsque t_a est égale ou supérieure à 35 °C, t_c est inférieure à t_a mais lorsque t_a est inférieure ou égale à 33 °C, t_c est alors supérieure à t_a . Lorsque t_a et t_c sont toutes deux au-dessus de 31 °C, les ouvrières n'exécutent pas d'AF. En-dessous de cette température, on observe pourtant le comportement. Lorsque la température chute, le pourcentage d'AF augmente. Le tableau I donne la corrélation (r) durant 3 j entre %AF et t_a d'une part et %AF et t_c d'autre part, ainsi que les corrélations partielles. Celles-ci sont environ 4 fois plus fortes pour %AF et t_c que pour %AF et t_a . Cela indique que la température du rideau a une influence plus grande que la température ambiante sur le pourcentage d'abeilles qui exécutent un AF et cela corrobore l'hypothèse de Woyke et al. (2004) selon laquelle les ouvrières qui exécutent un AF réagissent plutôt à la température autour d'elles à la surface du rideau qu'à la température ambiante.

***Apis dorsata* / battement de l'abdomen / corrélation avec la température / Philippines**

Zusammenfassung – Das Abdomenschnippen bei *Apis dorsata breviligula* Arbeiterinnen korreliert mit der Oberflächentemperatur des Bienenvorhangs im Nest. *Apis laboriosa* und *Apis dorsata* Arbeiterinnen im Bienenvorhang der Nestoberfläche zeigen ein dorso-ventrales Schnippen des Abdomens, ein Verhalten das eine wichtige Rolle im Leben der Kolonie zu haben

scheint. Es könnte beispielsweise ein Signal für Bienen im Nest darstellen, dass geheizt werden muss. Wir untersuchten, ob und wie gut die Umgebungstemperatur (t_a) oder die Temperatur der Nestoberfläche (t_c) mit dem Prozentsatz der Bienen korreliert, die ein Abdomenschnippen zeigen (%AF). In der Region von Los Baños auf den Philippinen wurden vom 1.–6. März 2004 zwei *A. dorsata breviligula* Nester beobachtet. Die Aktivitäten der Arbeiterinnen auf der Oberfläche des Nestvorhangs wurden mit einer Videokamera im Abstand von 1 m aufgezeichnet, und t_a und t_c wurden mittels eines elektronischen Thermometers registriert. In 210 Videoaufnahmen zeigten 508 von insgesamt 1260 beobachteten Bienen ein AF Verhalten. Abbildung 1 zeigt, dass t_c niedriger war als t_a , wenn t_a 35 °C oder mehr betrug. Wenn jedoch t_a unter 33 °C lag, dann war t_c höher als t_a . Wenn sowohl t_a als auch t_c bei über 31 °C lagen, zeigten die Arbeiterinnen im Nestvorhang kein AF. Unter dieser Temperatur wurde das Verhalten jedoch beobachtet. Mit abnehmender Temperatur stieg der Prozentsatz an AF-Bienen an. Die Korrelation zwischen %AF und t_a schwankte innerhalb der 3 Tage von $r = -0.930$ bis $r = -0.985$, und zwischen %AF und t_c von $r = -0.941$ bis $r = -0.994$ (Tab. I). Die partiellen Korrelationen zwischen %AF und t_a

schwankten innerhalb der 3 Tage jedoch zwischen $r = -0.126$ und $r = -0.383$, und für %AF zu t_c zwischen $r = -0.421$ und $r = -0.715$. Demzufolge waren die partiellen Korrelationen (r) zwischen %AF und t_c etwa viermal höher als zwischen %AF und t_a . Dies bedeutet, dass die Temperatur im Bienenvorhang einen grösseren Effekt auf den Prozentsatz der AF-Bienen zu haben scheint als die Umgebungstemperatur und stützt damit die Hypothese von Woyke (2004), dass Arbeiterinnen, die ein AF-Verhalten zeigen, stärker auf die Temperatur in der unmittelbaren Nestumgebung reagieren als auf die Lufttemperatur.

***Apis dorsata* / Abdomenschnippen / Nestvorhang / Temperaturkorrelation / Philippinen**

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