FLIGHT ACTIVITY REACTION TO TEMPERATURE CHANGES IN *Apis dorsata*, *Apis laboriosa* and *Apis mellifera*

Jerzy Woyke[1], Jerzy Wilde[2], Maria Wilde[3]

[1]Apiculture Division, Agricultural University, 166 Nowoursynowska, 02-787 Warszawa, Poland, e-mail: woyke@alpha.sggw.waw.pl
[2]Apiculture Division, Warmia-Mazury University, Olsztyn Poland
[3]Dabur Apiculture Centre, Jugedi, Chitwan, Nepal

Received 10 July 2003; accepted 4 November 2003

Summary

A. laboriosa lives in the Himalayas under harsh conditions. We compared the start of flight activity of *A. laboriosa* with that of the closely related *A. dorsata* living in territories with a higher temperature. We compared also the reaction of flight activity to temperature changes in *A. laboriosa* with that of *A. mellifera* living in similar temperature conditions. The results show that closely related *A. dorsata* workers started foraging at a temperature of 18°C, and *A. laboriosa* at a lower temperature of 10°C. However, the unrelated *A. laboriosa* and *A. mellifera* living in territories under similar ambient conditions started foraging at the same temperature of 10°C. The increase in temperature to 12°C resulted in a 10-fold increase in the number of foragers leaving the nests of both species, and their flight activity reaction to temperature changes was similar. High correlation between the temperature and the number of foragers was found in both species, at temperatures below 16°C. The environmental conditions in which the bees were living for longer period influence their behavior more than the phylogenic relationship.

Keywords: *Apis dorsata*, *Apis laboriosa*, *Apis mellifera*, flight activity, foraging, temperature, Himalayas, Nepal.

INTRODUCTION

Apis laboriosa bees live in the Himalayas under harsh conditions at altitudes of 1200 to 3600 m. Underwood (1990b) recorded active colony life at temperature range 4.5°C - 23.4°C. In autumn, when the temperature drops down, the colonies migrate to the lower warm temperature zone, where they survive the winter in combless clusters. However, Woyke at al. (2001b) observed that colonies which already resided in the warm zone reared brood throughout the winter at temperature 6°C - 24°C. Underwood (1990a) mentioned some flight activities of workers from combless clusters, however the foraging activity of workers from normal colonies was not investigated.

A. laboriosa occupies territory on the northern border of the *A. dorsata* homeland. *A. dorsata* lives mainly in the tropics. However, many *A. dorsata* swarms migrate in autumn and winter to the southern sub-tropical part of Nepal (Woyke et al. 2001a), where the winter temperature ranges between 6°C and 27°C (Thapa and Dangol 1991). That temperature range is very similar to that of the active life of *A. laboriosa* colonies. The lower range of temperatures recorded in *A. laboriosa* territory does not occur in *A. dorsata* territory, and the upper temperature range recorded in *A. dorsata* territory does not occur in *A. laboriosa* territory. However, a large temperature range is the same for the active life of both species mentioned. Therefore, we investigated whether the beginning of foraging of two closely related honeybees, living in territories with different extreme temperatures is different. Some consider even that both, *A. dorsata* and *A. laboriosa* are only different subspecies (Ruttner 1988).

However, the temperature range recorded in *A. laboriosa* territory can be found in temperate zones occupied by *A. mellifera*. Therefore we compared the reaction of flight activity to temperature changes in those two phylogenicaly distant honeybee species (Engel 1997) living in similar temperature conditions.

MATERIAL AND METHODS

Investigations on *A. dorsata* worker bees were conducted in the Institute of Agriculture and Animal Science in Rampur, Chitwan Nepal (latitude 27° 46’ North, longitude 84° 21’ East, altitude 200 m), from 18 October till 20 December 1999. The beginning of foraging activity was observed on 9 to 65 colonies located on a water tank tower or on a dormitory building (Table 1). The colonies were observed at weekly intervals, starting at 8:00 h, in total 9 times. The activity of some colonies was recorded using a video camera. Field observations were conducted in December, when the morning temperature was low. Temperature and time of the appearance of first *A. dorsata* foragers on flowers of mustard *Brassica campestris* were recorded periodically.

Whole day reaction of flight activity to temperature changes was compared between *A. laboriosa* and *A. mellifera*.

Investigations on *A. laboriosa* were conducted in Kyumi, Nepal, on the Annapurna mountain slope at the Modi Khola river, near Landrung in the Kasaki district (lat. 28° 22’ N. long. 83° 50’ E. alt. 1250 m). This was probably the Landrung cliff site observed by Underwood (1990b). Here, 16 normal nests of *A. laboriosa* were identified. We observed foraging activity of workers from one colony. The observations were conducted on the 1st and 2nd December 1999. We observed the bees from the other side of the river, at a distance of 28 m from the nest. In both places, Rampur and Kyumi, the foragers were observed through binoculars (12 x 50, Zenith) fixed to a tripod.

Comparative flight activity reaction to temperature changes in *A. m. mellifera* was investigated in the Apiculture Division, of the Agricultural University in Warsaw, Poland (lat. 52° 20’ N, long. 21° 00’ E, alt. 105 m). Only those results of observations are presented here, which were collected on days with similar temperature and weather conditions as in Kyumi. This happened on the 4 and 26 April 2001. In both places, a count of the number of foragers leaving the colony over a 5 minute period was conducted every 30 min from 8:00 to 17:00 h in Kyumi and from 7:00 to 20:00 h in Warsaw.

The air temperature was recorded in all three places using a digital thermo hydrometer (Model No ETHG-912, Oregon Scientific), which was placed in the shade, 1 m above the ground.

RESULTS

Beginning of flight activity of *A. dorsata*

Table 1 shows that during the first 3 weekly observations, the temperature at 8:00 h was above 20°C, and at these temperatures the workers had already foraged. On the 8 November the temperature at 8:00 h was 19°C, and the foragers were inactive. However, half an hour later, the first workers started foraging although the temperature did not change. On the 15 November the temperature at 8:00 h was 18°C, and the foragers were inactive. However, 10 min later, at the same temperature, they started

Table 1

Beginning of flight activity of *Apis dorsata* worker bees in Rampur, 1999
(Observations started at 8:00 h)

Date	Temp. °C at 8:00 h	Beginning of flight		No. colonies *
		Temp. °C	Time	
Water Tank Tower				
18. 10	25	already active		9
25. 10	23	already active		11
1. 11	21	already active		23
8. 11	19	**19**	8:30	23
15. 11	18	**18**	8:10	27
22. 11	16	**16**	8:30	29
7. 12	15	**17**	10:00	65
14.12	14	**18**	11:00	65
Dormitory Building				
20. 12	13	**18**	11:30	18

* The number of colonies changed, because new swarms were arriving

to fly. On the 22nd November, the temperature at 8:00 h was 16°C, and the foragers were inactive. They started foraging half an hour later at the same temperature. During the next three weekly observations (7 - 20 Dec.) the temperature at 8:00 h had dropped, however, the workers started foraging later at higher temperatures 17°C - 18°C (Table 1). Thus, during the six observations (8 Nov. - 20 Dec), the workers started foraging at 16°C - 19°C, mean = 17.7°C ± s.d. 1.03, s.e 0.42. The results show that a lower temperature at 8:00 h results in a later beginning of foraging, nevertheless the flights start at lower temperatures. But when the temperature drops below 16°C, the workers require more time to heat the outside layer of workers of the nest curtain, and as a result, they start foraging later at higher temperatures.

Worker bees in the field were not found at temperatures lower than 17°C - 18°C. This occurred in December between 10:00 h and 11:00 h when the mustard *Brassica campestris* was flowering *en masse* on many fields. At this time many *A. cerana* and *A. mellifera* were already foraging.

Reaction of flight activity to temperature changes in *A. laboriosa* worker bees

December 1 was a sunny day and Dec. 2 cloudy after 13.00 h. On 1 December, the sun rose, in nearby Pokhara city, at 6:44 h and set at 17:13 h. The day was 10:19 h long.

Figs 1A and 1B show that single foragers began to leave the colony in the morning at a temperature of 9°C. By 9:30 h the temperature had risen to 10°C, and the number of foragers leaving the colony increased to 7 workers. A further rise of the temperature by 2°C, up to 12°C resulted in a 10-fold increase in the number of foragers leaving the colony (78-84). At 11:00 h the temperature increased by 4°C to 16°C, which was related to a 2.2 times, increase in the number of foragers leaving the nest on

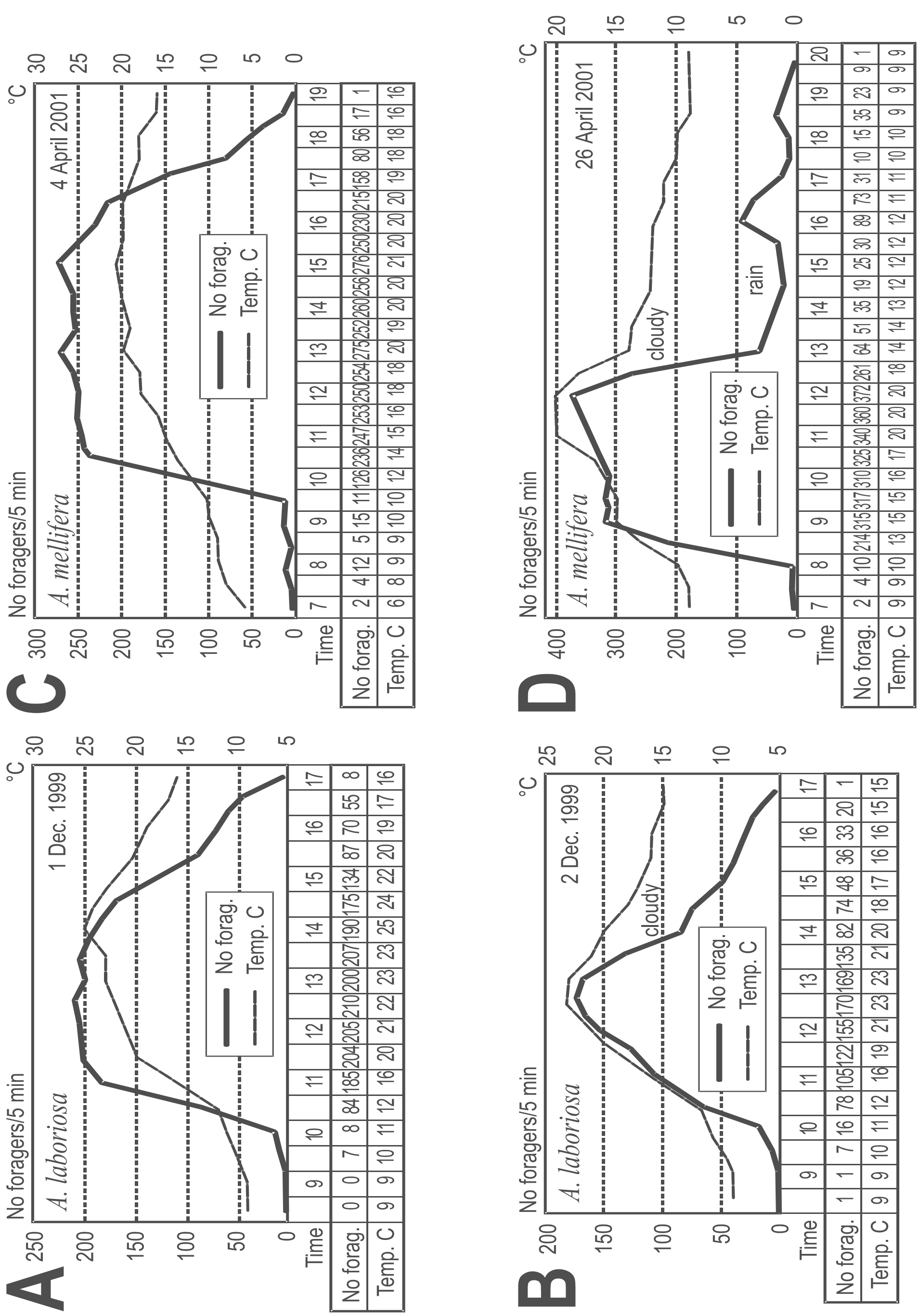

Fig. 1. Flight activity of *A. laboriosa* and *A. mellifera*. A - *A. laboriosa* during sunny day, B - *A. laboriosa* during a day with a cloudy afternoon, C - *A. mellifera* during sunny day, D - *A. mellifera* during a day with a cloudy afternoon.

the sunny day of 1 December. The correlation coefficient between the temperature, in the range of 10 - 16°C and the number of foragers leaving the nest during both days was r = 0.90, n = 8, P = 0.002, indicating a statistically significant relationship between those data. The R-squared statistic indicated that the model explains 81.3% of the variability in the number of foragers. Thus, it can be concluded that within temperature range 10 - 16°C, temperature is the prevailing factor determining flight activity of *A. laboriosa*.

The sunny day 1 Dec. between 11:30 and 13:30 h, the temperature varied between 20°C and 23°C, and the number of foragers between 200 and 210 (Fig. 1A). The correlation coefficient between those data was r = - 0.04, n = 5, P = 0,95. Thus, within that range of temperatures no statistically significant relationship was found between temperature and the number of foragers. At those temperatures, factors like nectar availability and others played probably the more important roles.

At 14:00 h, i.e. 3 h before sunset, the number of foragers started to decrease until the end of flight activity, although the temperature at 14:00 and 14:30 h was quite high. The correlation coefficient between the temperature range 25°C and 16°C and the number of foragers was now r = 0.99, n = 7, P < 0.001, being highly significant.

The slope was 24, - 0.1 and 27 foragers per 1°C, for the three daily periods respectively. Thus, high reaction of flight activity to temperature changes occurred during the morning and afternoon hours.

Fig. 1A shows that fewer workers have been flying afternoon, than forenoon at the same temperatures. This could be due to the direction of increasing or decreasing of the light intensity of sun, temperature and nectar availability.

The correlation coefficient between temperature and flight activity during the whole day was r = 0.77, n = 16, P = 0,0004, being weaker than in the morning and evening, however, stronger than during the midday hours. The morning and evening data dominated the results.

Fig. 1B shows that clouds in the sky decreased both the temperature and the number of foraging workers. The number of bees leaving the colony during the cloudy part of the day was lower than during sunny time, at the same or lower temperature.

Reaction of flight activity to temperature changes in *A. m. mellifera* worker bees

In Poland, the 4 April was sunny, whereas on the 26 April, clouds covered the sky at 12:30 h. The clouds darkened gradually, and at 14:30 h it started to rain. The sun rose in Warsaw on the 4 April at 6:05 h and set at 19:08 h. The day was 13:03 h long.

Figs 1C and 1D show that only single foragers left the colony in the morning, at temperatures lower than 10°C. When the temperature rose to 10°C, 10 - 15 workers left the colony during a 5 min period. Further temperature rise by 2°C, up to 12°C, at 10:00 h resulted in a 10-fold increase (126) of the number of foragers leaving the colony. That number was doubled (253) at 11:30 h, when the temperature rose to 16°C (Fig. 1C). Correlation coefficient between temperature range 10°C - 16°C and the number of foragers living the hive during both days was r = 0.96, n = 11, P < 0.001. The R-squared statistics explained 92.58% of the variability in the number of foragers. Thus within that range, the temperature was the factor determining the number of foragers. Between 12:00 and 16:00 h, on the 4 April, the temperature varied between 18°C and 21°C, and the number of foragers between 250 and 276. The correlation coefficient between temperature and the number of foragers was r = 0.35, n = 9, P = 0.35. Thus, no correlation was found for the midday hours. At 16:00, i.e. 3 h before sunset, the number of foragers started to decrease until the end of flight activity, although the temperature at the beginning was still high. The correlation coefficient between the temperature range 20°C and 16°C, and the number of foragers was now r = 0.96, n = 7, P = 0.0004. The slope was 50, 4.8 and 54 foragers per 1°C, for the three daily periods respectively. Thus, the reaction of flight activity to temperature changes was the highest during the morning and afternoon periods.

The correlation coefficient between the temperature and flight activity during the whole day was r = 0.62, n = 21, P = 0.003, being weaker than in the morning, and evening, however stronger than during midday calculated separately.

Figure 1C shows that the decrease of temperature at 12:30 h coupled with clouds in the sky, significantly decreased the overall number of foragers leaving the colony.

DISCUSSION

Our results concerning the beginning of flight activity of *A. dorsata* agree with those of Dyer and Seeley (1987) according to which *A. dorsata* workers are not able to fly at temperatures lower than 17°C.

According to Lundie (1925) the lowest temperature at which the flights of *A. mellifera* ligustica began was 10°C, but the flight commenced normally between 12°C and 14°C in April. Thus, it can be concluded, that in a similar temperature range and weather condition, the starting temperature for foraging and response of flight activity to temperature changes are similar among *A. laboriosa*, *A. mellifera mellifera* and *A. mellifera ligustica*.

The lower number of foragers flying after noon than before noon, at the same temperature, may be due in great part to the direction of meteorological changes. Woyke et al. (2000) found that during an eclipse of the sun, a lower number of *A. mellifera* workers left the hive before the maximal eclipse when the light intensity decreased, than after the eclipse, when light intensity increased. Thus, although strong correlation between temperature and flight activity was found, some other characters, like the direction of light intensity changes and others, influence also the flight activity. However, both species *A. laboriosa* and *A. mellifera* reacted similarly.

Szabo (1980) found a significant correlation (r = 0.78) between temperature (range 14°C - 24°C) and flight activity of *A. mellifera*. However, at higher temperatures, no correlation between those two factors was found, (Domagała - Lipińska 1962 and Lee et al. 1987), and at the highest temperatures, above 30°C, flight activity decreased with temperature increase (Gary 1967 and Woyke 1992). Those differences are explained by our results, according to which the correlation between air temperature and flight activity is strong at lower temperatures, but is weaker or does not exist at higher temperatures.

CONCLUSION

The prevailing higher temperature at which *A. dorsata* workers are foraging is coupled with the beginning of flight activity at higher temperature, than in *A. laboriosa* and *A. mellifera*. This is of no significance in the tropics. However, it is disadvantageous on the outskirts of the territory, where the temperatures are lower. Other bees like *A. cerana* and *A. mellifera* are already foraging at those temperatures. This indicates that territories in which the morning temperatures are lower than 18°C, are the expansion ones in which *A. dorsata* is not able to take advantage of all food available.

When the early morning temperatures are lower, *A. dorsata* workers start foraging at higher temperatures. This suggests that more heat is required to worm the outer worker layer of nest curtain.

A. laboriosa workers start foraging at 10°C, which is at temperature 6°C - 8°C lower than the closely related *A. dorsata* workers do. Thus, the Himalayan bee can collect food in lower temperatures.

The start of foraging, in relation to ambient temperature, and the reaction of flight activity to temperature and other meteorological changes during the day, were similar in both species, *A. laboriosa* and *A. mellifera*. High correlation between the temperature and the number of foragers was found in both species, for morning hours at temperatures below 16°C. Although the days were in Poland 2:44 h longer than in Nepal, workers of both species began to decrease flight activity 3 h before sunset.

Hence, the start of foraging of two closely related honeybees *A. dorsata* and *A. laboriosa* living in territories characteristic of different temperature range occurs (within the same temperature range), at different temperatures. Whereas, both the start of foraging and the response of flight activity to temperature changes is similar in two phylogenicaly distant honeybee species, *A. laboriosa* and *A. mellifera* living in territories of similar temperature range. This shows that the environmental conditions in which the bees were living for longer period influence their behavior more than the phylogenic relationship.

ACKNOWLEDGMENTS

We would like to thank very much Mr. A. Burman, the chairman of Dabur Company for providing us with the facilities to conduct the investigations in Dabur Apicultural Centre, Jugedi, Nepal; and R. Kolasinski MSc for organising the opportunity to visit the centre, along with his encouragement and help.

REFERENCES

Domagała - Lipińska A. (1962) - Dzienna dynamika lotu pszczołowatych a temperatura. [Daily dynamics of flight of *Apidae* and temperature]. *Ecol. Polska* Ser B, 8:55-57.

Dyer F., Seeley T. D. (1987) - Interspecific comparisons of endothermy in honey-bees (*Apis*): deviations from the expected size-related patterns. *J. exp. Biol*. 127:1-26.

Engel M. S. (1997) - Phylogeny and behaviour in honey bee. *Ann. ent. Soc. Am*. 90:43-51.

Gary N. E. (1967) - Diurnal variations in the intensity of flight activity from honeybee colonies. *J. apic. Res*. 6:65-68.

Lee M. L., Choi S.Y., Cho Y. H. (1987) - Diurnal activity of the honey bees (*Apis mellifera*) at the hive entrance. *Korean J. Apicult*. 2:117-121.

Lundie A. E (1925) - The flight activities of the honeybee. *United States. Department of Agriculture, Department Bulletin* No 1328:1-38.

Ruttner F. (1988) - Biogeography and taxonomy of honeybees. *Springer-Verlag*, Berlin.

Szabo T. I. (1980) - Effect of weather factors on honey flight activity and colony weight gain. *J. apic. Res.* 19:164-171.

Thapa R. B., Dangol D. R. (1991) - A preliminary survey of bee flora at IAAS and its vicinity. IAAS Research Reports (1985 - 1991) (ed FP Neupane), Inst. Agric Anim. Sci., Rampur, Chitwan, Nepal: 59-65.

Underwood B. A. (1990a) - The behavior and energetics of high-altitude survival by the Himalayan honey bee, *Apis laboriosa*. Ph D thesis, *Cornell Univ*., Ithaca NY USA 146 pp.

Underwood B. A. (1990b) - Seasonal nesting cycle and migration patterns of the Himalayan honey bee *Apis laboriosa*. *Nat. geogr. Res*. 6:276-290.

Woyke J. (1992) - Diurnal flight activity of African bees *Apis mellifera adansonii* in different seasons and zones of Ghana. *Apidologie* 23:107-117.

Woyke J., Jasiński Z., Fliszkiewicz C., Woyke H. (2000) - Flight activity of *Apis mellifera* foragers at hive entrance during 86% eclipse of sun. *Pszczel. Zesz. nauk*. 44:239-252.

Woyke J., Wilde J., Wilde M. (2001a) - Swarming, migration and absconding of *Apis dorsata* colonies. Proceedings VII Internat. Conf. on Tropical Bees, and V Asian Apicultural Assoc. Conf., Chiang Mai, 19 - 25 March, 2000:183-188.

Woyke J., Wilde J., Wilde M. (2001b) - A scientific note on *Apis laboriosa* winter nesting and brood rearing in the Himalayas. *Apidologie* 32:601- 602.

REAKCJA AKTYWNOŚCI LOTNEJ NA ZMIANY TEMPERATURY U *Apis dorsata*, *Apis laboriosa* I *Apis mellifera*

Woyke J., Wilde J., Wilde M.

Streszczenie

Pszczoła skalna *A. laboriosa* żyje w Himalajach w surowych warunkach. Porównywaliśmy początek aktywności lotnej *A. laboriosa* oraz pszczoły olbrzymiej *A. dorsata* żyjącej w tropikalnych warunkach. Porównywaliśmy również zmiany w aktywności lotnej w zależności od temperatury u *A. laboriosa* i *A. mellifera* żyjących w podobnych warunkach temperatury. Otrzymane wyniki wykazały, że *A. dorsata* rozpoczynała aktywność lotną w temperaturze 18°C, a blisko z nią spokrewniona *A. laboriosa* w niższej temperaturze 10°C. Jednak filogenetycznie daleko spokrewnione *A. laboriosa* i *A. mellifera* żyjące w zbliżonych warunkach klimatycznych rozpoczynały loty w temperaturze 10°C. Wzrost temperatury do 12°C spowodował 10 krotny wzrost liczby zbieraczek wylatujących z gniazd u obydwu gatunków. Reakcja aktywności lotnej na dalsze zmiany temperatury była podobna u obydwu gatunków pszczół. W temperaturze poniżej 16°C, stwierdzono wysoką korelację między liczbą zbieraczek wylatujących z gniazda, a temperaturą otoczenia. Tak więc warunki otoczenia, w których pszczoły żyły przez dłuższy okres, wywarły większy wpływ na ich zachowanie niż spokrewnienie filogenetyczne.

Słowa kluczowe: *Apis dorsata*, *Apis laboriosa*, *Apis mellifera*, aktywność lotna, temperatura, Himalaje, Nepal.